

NAVAL POSTGRADUATE SCHOOL

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THESIS

ELASTIC-PLASTIC FRACTURE TOUGHNESS
TESTING METHODS

by

Wayne Kurt Tritchler

December 1983

Thesis Advisor: K. D. Challenger

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Testing Methods

by

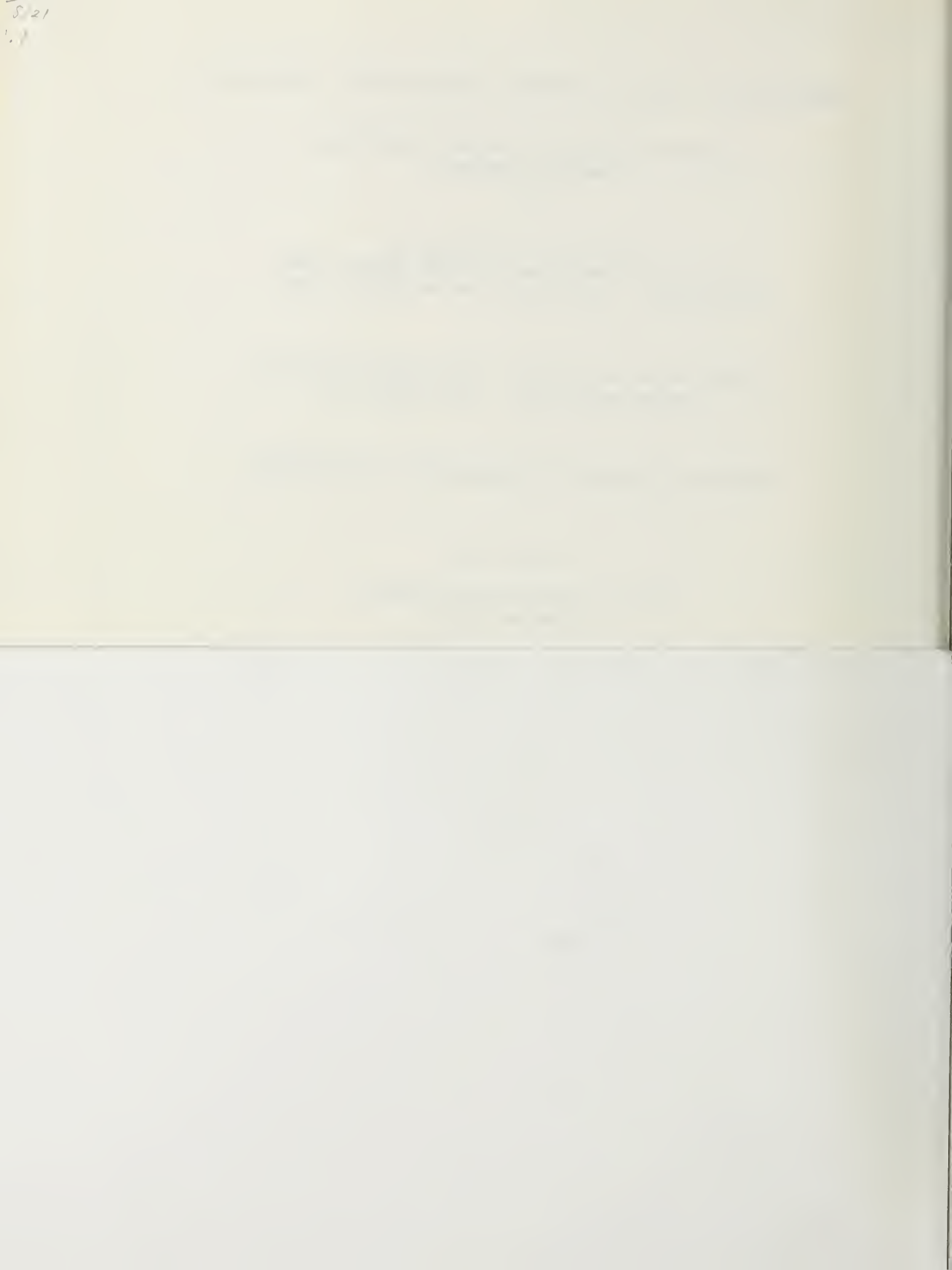
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requirements for the degree of

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ABSTRACT

An interactive computerized experimental procedure is presented for obtaining the elastic-plastic fracture toughness (J_{IC}) for a material. The process employs a bend type, single specimen approach by using the measured unloading crack opening displacement (COD) compliance to obtain the crack length. Data are taken, manipulated and plotted during the test to provide the operator with the necessary information to control the testing machine. The program automatically plots the J versus crack extension curve and determines J_{IC} upon completion of the test. A second program is presented to assist the operator in fatigue precracking the specimen. A third program is used to recall, list and plot the data that were stored on diskette during the test.

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I dedicate this work to my wife Barbara and sons, Victor and Michael. While they may not understand this work they have provided the encouragement and support required to complete it.

I. INTRODUCTION

A. GENERAL

The toughness of a material is a measure of the energy per unit volume required to cause fracture. It can be quantified by simply taking the area under the true stress strain curve from a simple tension test [Ref. 1]. The practical usefulness of this measurement is limited however, because it provides no information on the material's ability to resist crack propagation. Since all real structures contain notches or cracks of some sort, by design or otherwise, which act as stress concentrators, another measurement of toughness was developed called fracture toughness.

The fracture toughness (K_{IC}) of a material is a measure of the resistance of the material to fracture in the presence of a defect. K_{IC} is defined as the plane strain fracture toughness and is used to quantify a material's resistance to crack propagation [Ref. 2]. The American Society for Testing and Materials (ASTM) developed Standard E399-83 [Ref. 3] which establishes precise details for accepted testing procedures. The standard also provides rigid criteria for the specimen size and geometry to ensure plane strain conditions exist at the tip of the crack.

The J-integral method, developed by Rice in 1968, provides a means of including plastic deformation at the crack tip [Ref. 4]. J is a measure of the intensity of the entire elastic-plastic stress-strain field that surrounds the crack tip. J_{IC} is defined as the value of J at the onset of cracking. J-integral testing has gained acceptance as a valuable means of evaluating a metallic material's resistance to crack initiation as demonstrated by establishment of ASTM Standard E813-81 [Ref. 5]. The measured value of J_{IC} has practical applications in measuring the effects of metallurgical variables, heat treatments, and weldments and is being used by researchers today to make such quantitative distinctions [Ref. 5-7].

B. J_{IC} VERSUS K_{IC} TESTING

The procedures established by ASTM Standard E399-83 for obtaining K_{IC} impose minimum specimen size requirements that cause difficulty when testing materials that possess high toughness. The specimen thickness must be sufficient to cause plane strain conditions to exist [Ref. 3]. Hertzberg [Ref. 2] presents the empirical equation developed by Brown and Srawley [Ref. 8]:

$$t \text{ and } a > 2.5 * (K_{IC}/Y_s)$$

where

t = specimen thickness

a = crack length

K_{IC} = plane strain fracture toughness

Y_s = yield strength

A similar analysis for J-integral test specimens reveals that:

$$b \text{ or } B > 25 * (J_{IC}/F_s)$$

where

b = initial uncracked ligament

B = specimen thickness

J_{IC} = anticipated value if J_{IC}

recheck when test is completed

F_s = flow stress $[(Y_s + U_{ts})/2]$

Hertzberg takes this result one step further by showing that J_{IC} equals $(K_{IC})^2/E$ (where E equals the material's elastic modulus) for J_{IC} . By dividing the two equations one sees that:

$$(K_{IC} \text{ specimen size}) > 20 * (J_{IC} \text{ specimen size})$$

thus, because the J-integral allows plastic deformation, one of its most significant advantages is that a satisfactory specimen can be obtained at one-twentieth (1/20) of the thickness of a K_{IC} specimen. This not only means smaller specimens may be used but, also, smaller testing machines are required and therefore costs are reduced. [Ref. 2]

Although J_{IC} and K_{IC} provide a different measure of toughness, J_{IC} can be used to estimate K_{IC} . ASTM Standard

E813-81 [Ref. 5] provides limited guidelines on the relationship between the two.

C. PURPOSE AND SCOPE OF RESEARCH

The purpose of this thesis is to develop the procedures required to obtain J_{Ic} from J-integral test results using equipment currently available within the Materials Science group of the Mechanical Engineering Department at the Naval Postgraduate School (NPS). A list of the major equipment follows:

- a. Series 810 MTS machine
- b. HP-9826 computer with internal disk drive
and 320K random access memory
- c. HP-3497A data acquisition system
- d. HP-3437A voltmeter
- e. HP-2671G thermal printer
- f. HP-7225B graphics plotter

Figure 1 shows the system layout.

The test method developed is to comply with ASTM Standard E813-81 [Ref. 5], be easy for others to use, and require a minimum of operator interaction. It is specifically designed for use with three point bend specimens using a single vice multiple specimen approach. The method developed and presented here covers the entire test, including specimen preparation, precracking, testing, and validation of results.

II. NATURE OF THE PROBLEM

A. J-INTEGRAL

The J-integral is a mathematical expression used to characterize the near tip stress-strain environment of cracked elastic-plastic bodies [Ref. 9]. It is a path independent line integral that surrounds the crack tip for non-linear plastic metallic materials [Ref.5]. The equation developed by Rice is [Ref. 4]:

$$J = \int_{\Gamma} (W dy - T \cdot (\partial u / \partial x) ds)$$

where

W = loading work per unit volume, or for elastic bodies, strain energy

Γ = the path of the integral, which encloses the crack tip

ds = increment of the contour path

T = outward traction vector on ds

u = displacement vector at ds

x,y,z = rectangular coordinates

$T \cdot (\partial u / \partial x) ds$ = the rate of work input from the stress field into the area enclosed by Γ .

Figure 2 provides a pictorial representation of this equation.

The mathematical expression developed by Rice [Ref. 4] has been manipulated and reduced to simpler forms for

specific specimen geometries. Rice, Paris, and Merkel [Ref. 10] reduced the J-integral expression for a three point bend specimen to:

$$J = \frac{2 * A}{b * B}$$

where

J = resistance to crack initiation

A = area under load versus load line
displacement curve

b = uncracked ligament

B = specimen thickness

This thesis is not intended to redevelop the J-integral but rather apply it, therefore only the result is presented here.

More recent work by Ernst, Paris, and Landes [Ref. 11] corrects the calculation of J due to crack growth by means of the following equation:

$$J_{(i+1)} = (J_i + (n/b)_i * A_{i,i+1}) * (1 - (Y/b) * (a_{i+1} - a_i))$$

where

J_(i+1) = current value of J

J_i = last J computed

n = 1 for three point bend type specimens

A_{i,i+1} = area enclosed by the actual test
record and lines of constant
displacement d_i and d_{i+1}

Y = 1 for three point bend type specimens

b = current uncracked ligament

W = specimen width

a_1 = last crack length

a_{i+1} = current crack length

Correcting for crack growth during the test is necessary when using a single specimen approach as used by this method.

The blunting line defined as:

$$J = 2 * F_s * \Delta a$$

where

F_s = flow stress

Δa = change in crack length

approximates apparent crack advance due to crack tip blunting in the absence of slow-stable crack tearing. It is plotted on the J versus crack extension plot. A linear regression fit through the applicable data points is then plotted. The intersection of the two lines is by definition J_{IC} (see Figure 3). [Ref. 5]

B. PREVIOUS WORK

The early experimental methods used to obtain J_{IC} required the preparation of several specimens. Each specimen received a different load. The specimens were then heat tinted (to identify crack length) and broken apart. Each specimen provided one data point on the J versus crack extension curve, commonly referred to as the J - R curve [Ref.

9 and 11]. Checks were then performed on the validity of the data. A minimum of four valid data points were required to obtain a linear least squares fit and hence J_{IC} [Ref. 5,10 and 12].

Researchers over the last five years have developed a much improved test method whereby a single specimen can be used. Today's computerized data acquisition equipment and data manipulation are ideally suited for the task. By relating the compliance (how much a specimen bends under a given load) to the crack length, all the data required to obtain the J-R curve can be collected by using a single specimen [Ref.11-16]. Clarke [Ref.16] states that prior to the use of computers the time required for data reduction to obtain the J-R curve was four to five hours. Using computerized, single specimen, unloading compliance methods it is now possible to obtain the J-R curve in a matter of twenty to thirty minutes after the test starts. The obvious savings in specimen preparation and data reduction have made the J-integral a valuable means of analysis where no practical means previously existed.

C. TEST CRITERIA

The test method developed in this thesis is specifically designed for use on a three point bend specimen. It utilizes the single specimen approach by relating the crack opening displacement (COD) compliance to the crack length.

The following equations are currently used by DTNSRDC. For bend specimens with a span to width (S/W) ratio of 4.0, Dr. J. Joyce [Ref. 17] of the United States Naval Academy determined:

$$a/W = 0.998265 - 3.81662 * U - 1.80596 * U^2 + 32.31038 * U^3 - 44.15665 * U^4 - 52.67876 * U^5$$

where

a = crack length

W = specimen width

$$U = \frac{1}{\left(\frac{4 * B_e * E * W * compl}{S} \right)^{1/2} + 1}$$

where

B_e = effective thickness = $B_{max} - (B_{max} - B_{min})^2 / B_{max}$

E = material's elastic modulus

S = span between supports

W = specimen width

compl = compliance = 1/slope of the load versus COD line for the specific unloading.

The reason for using the single specimen approach has already been presented. The reasons a bend type specimen and COD type unloading compliance are used are:

- a. Three point bend specimen geometry is better suited than compact tension specimens for testing weldments.
- b. Three point bend specimen geometry is also easier to machine than compact-tension specimens.

- c. COD voltage readings are less susceptible to noise than linear variable differential transformer (LVDT) voltages used to measure load line displacement.
- d. The COD compliance equation affords 0.1% fitting accuracy and allows comparison of results with DTNSRDC test data [Ref. 17].

III. TEST METHOD

A. OVERVIEW

A J-integral test can be divided into three distinct steps, 1) pre-test, 2) test, and 3) post-test. Each of these are described in greater detail in this chapter and presented as a step by step procedure in Appendix A.

After the specimen is machined it must be precracked using cyclic fatigue loading to minimize residual stresses and create a sharp crack tip [Ref. 5]. A computer program was developed to assist the operator in accomplishing this. The program computes the loading parameters for precracking in accordance with ASTM Standards E399-83 and ASTM E813-81 [Ref. 3 and 5]. The operator uses this information to run the MTS machine.

During the J-integral test a second computer program collects and records the load, COD, and load point displacement (deflection). These data are used by the program to determine J and the amount of crack extension for each operator controlled unloading cycle. An unload cycle consists of decreasing the load by 10% of the expected maximum load and reloading to the original load point. The program provides the operator with a real-time graphical representation of the any two parameters (load versus COD or deflection) during the test. It will also plot the J-R

curve and compute J_{Ic} upon completion of taking all the test data. Data are stored on diskette to serve as a record and allow future recall listing or plotting.

The post-test process includes heat tinting the specimen to aid in visual verification of crack extension upon completion of the test as required by ASTM Standard E813-81 [Ref. 5].

B. SPECIMEN PREPARATION

Figure 4 shows specifically the dimensions used in preparing eight specimens from two different one inch thick welded plates of HY-80. One plate was preheated while the other was not. It was necessary to reduce the width to approximately 0.95 inches to remove the distortion (bow) created by the weld. Four specimens were prepared from each plate, the machined notch was placed in the weld metal for two and in the base metal for the other two. The clip gage (used to measure COD) is attached to the top of the specimen by means of two cut razor blades. The blades are held down by small straps which allow adjustment of the initial gap. The initial gap is set to 0.475 inches, the calibrated zero setting for the clip gage, by means of a machined gage tool that rests in the specimen's machined notch. This method is also used by DTNSRDC.

Two additional holes are drilled and tapped for retaining a small bracket on the face of the specimen. The

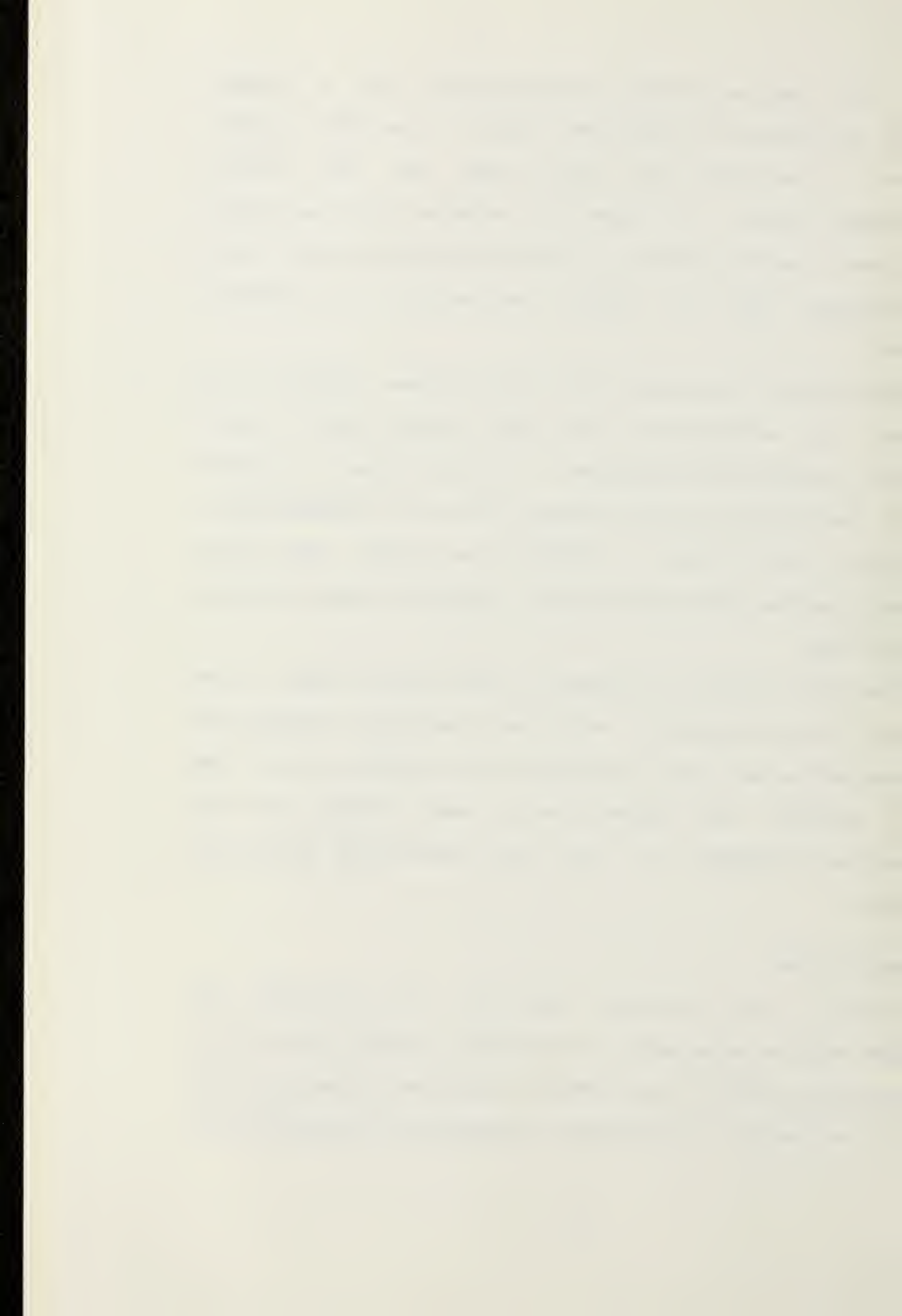
bracket is used to provide a sensing point for a linear variable differential transformer (LVDT). The LVDT signal is used to calculate the area under the load versus displacement curve. At present the external LVDT is unable to control the MTS machine so the current method uses the MTS' internal LVDT to measure deflection via actuator movement.

Clarke [Ref. 16] states that side grooves improve the accuracy of calculating the crack length when using unloading compliance procedures. The side grooves reduce plastic deformation on the surface and aid in propagating a straighter crack front. DTNSRDC has found 20% side grooving produces the best results, hence the same was used for this work.

After the specimen is prepared a test record sheet (see Appendix B) is completed. Notch and side groove depths can be measured using a dial indicator with a needle tip. The record provides the operator with ready access to the information necessary to run the precracking and test programs.

C. PRECRACKING

Before the J-integral test can be performed the specimen must be precracked to establish a sharp crack tip. ASTM Standards E813-81 and E399-83 establish parameters that must be met during precracking to prevent over-stressing the



specimen or propagating the crack through the entire width. Precracking is accomplished with the aid of a program called "PRECRACK" which will compute loading requirements based upon these parameters.

The program, written in HP-Basic, affords flexibility by allowing the use of different bend specimen sizes and materials. It is easy to use due to its interactive design and easy to modify should such a need arise. A listing of "PRECRACK" is provided in Appendix D.

The operator is requested by the program to enter specific specimen data. The program will compute the initial maximum and minimum loads and change in the associated stress intensity factor (ΔK). If this ΔK exceeds $40 \text{ ksi}\cdot\text{in}^{1/2}$ then new maximum and minimum loads are computed. The operator is responsible for ensuring the MTS machine is operating within the prescribed limits. The operator can obtain a hard copy of the entered and computed data for record purposes (see Appendix G).

The MTS machine produces cyclic loading by means of an inverted (compressive load) haversine wave.

The operator must periodically interrupt the cyclic loading and measure the current crack length by manually loading and unloading the specimen (determine the specimen's compliance). The program computes the new crack length and new loading limits. During the last 50% of precracking:

$$P_{\max} < .4P_L$$

where

P_{max} = maximum load

$$P_L = [(4/3) * (B * b^2 * F_s / (2 * H_s))]$$

where

B = net thickness (B_{min} if specimen has side grooves)

b = current uncracked ligament (W-a)

F_s = flow stress ((Y_s+U_{ts})/2)

H_s = half span

and $\Delta K/E < 0.005 \text{ mm}^{1/2}$ (0.001 in^{1/2}) whichever, produces the least load [Ref. 5]. The program will automatically begin using these parameters when the most recently calculated crack length exceeds this 50% of the required extension to reach a/W = 0.6. This value is used because it is the optimum crack length with which to begin the J-integral test [Ref. 5].

D. J-INTEGRAL TEST

The J-integral test is performed by slowly applying a load to the specimen and periodically unloading it by 10% of the expected maximum load. The MTS machine is set up in stroke control with a very small inverted ramp function resulting in a loading rate of 0.005 inch/minute. The operator must again interrupt the MTS program and manually unload the specimen. Each unloading cycle (unload and reload) provides the necessary information to compute the current crack length. The crack length is then used to

determine the value of J up to that point. The computer program "J_INTGL" provides the operator with pertinent information during the test. Once the test is completed, the operator can obtain the J-R curve and value of J_{IC} (see Figure 4 and Appendix H). The program will use only data points between the offsets, (blunting line + 0.15mm) to (blunting line + 1.5mm) as required ASTM Standard E813-81 when computing the linear regression line. A minimum of four data points must be within the offsets and one must lie near (within 1/3 the overall range of Δa) the blunting line. Specific acceptability criteria for data is provided in ASTM Standard E813-81 [Ref. 5].

The program "J_INTGL" is the foundation of the test method, the single specimen approach would not be possible without it. The program collects, manipulates, displays and records all pertinent data during the test. A flow chart of "J_INTGL" is provided in appendix C. A listing of "J_INTGL" is provided in Appendix E.

Deflection measurements are presently taken using the LVDT installed in the MTS machine. A correction is therefore required to account for the system's compliance while loading a specimen. The correction was obtained by loading the system with a two inch thick piece of HY130 and recording the stroke reading for various loads. This process was checked three times with consistent (within 5%)

results. A plot of the data and the 4th order polynomial curve fit is included as Figure 5.

E. POST TEST VERIFICATION

The results must be verified upon completion of the test. ASTM Standard E813-81 presents the following criteria that must be met before the test can be considered valid:

1. Total crack extension (visually measured) must be within 15% of that recorded during the test.
2. b_1 and $B_{min} > 25 * J_{Ic} / F_s$ (all terms are as defined earlier except b_1 = post-fatigue uncracked ligament).
3. The slope of the linear regression fit to the data must be less than flow stress ($dJ/da < F_s$).

IV. RESULTS

A. TEST RESULTS

Specimen HY80-5B, prepared from the base metal of the preheated welded plate, was precracked, and tested resulting in a J_{IC} value of 142 kJ/m^2 . Figure 8 is a tracing of a photograph of the final fracture surface after heat tinting. All post test checks were completed and yielded satisfactory results. The J_{IC} value is in good agreement with previous tests of HY80 plate as conducted by DTNSRDC resulting in an average J_{IC} of 144 kJ/m^2 [Ref. 6].

Plots of J-R curve, load versus COD, load versus deflection and the are included as Figures 5, 6 and 7, respectively. The load versus deflection curve was obtained using the program "J_DATA", thus proving that the data is stored on disk, and is able to be recalled.

Data was taken at a nearly constant rate of 2.5 data points per second (150 per minute) while the program was executing.

Test results were verified following the guidelines provided by ASTM Standard E813-81. The fracture surface was enlarged by taking a photograph, a tracing of which is included as Figure 8. The observed crack length was 14.4% longer than the last recorded crack length. This is within the acceptable limit (recall ASTM requires $< 15\%$) but

because the clip gage reached its limit detector and caused the test MTS to stop between unloadings, it is possible some crack extension occurred after the last unloading cycle. This would help to explain the difference.

Additional information on this specific test is provided by being used in the example calculations shown in Appendix A. The exemplary computer output for each of the programs is also from specimen HY80-5B. (See Appendixes G, H and I).

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The method developed and presented by this work produces accurate and reliable results that meet the specifications established by ASTM Standard E813-81. Precracking specimen HY80-SB took approximately 2 hours and the J-test required approximately 2.5 hours including several pauses to manually verify several calculations. The time required for the processes will most likely decrease as operator experience and confidence increases.

All three computer programs have run successfully and perform as intended.

B. RECOMMENDATIONS

As with all first versions of computer programs as extensive as "J_INTGL", changes and improvements are to be expected. The following programming changes may be of value to future operators:

1. Display pertinent information (i.e. current crack length in both English and metric units (currently only metric is provided)).
2. Provide a means of storing the data arrays during the test without being required to rerun the entire

program (re-entering specimen data, conversion data, etc.)

3. Provide a means of eliminating a specific J-R data point from being used in obtaining the linear regression fit. This may be programmed to be accomplished automatically by applying Chauvenet's Criterion to the data.

Improvements in the current means of conducting the test can also be made, such as making the MTS control both loading and unloading using the same rate, requiring the operator to do no more than press a button or throw a switch. Lastly, pursue the use of the external LVDT, this will eliminate the need for correcting the deflection reading and speed up the rate of data acquisition.

MTS 810
Material Test System

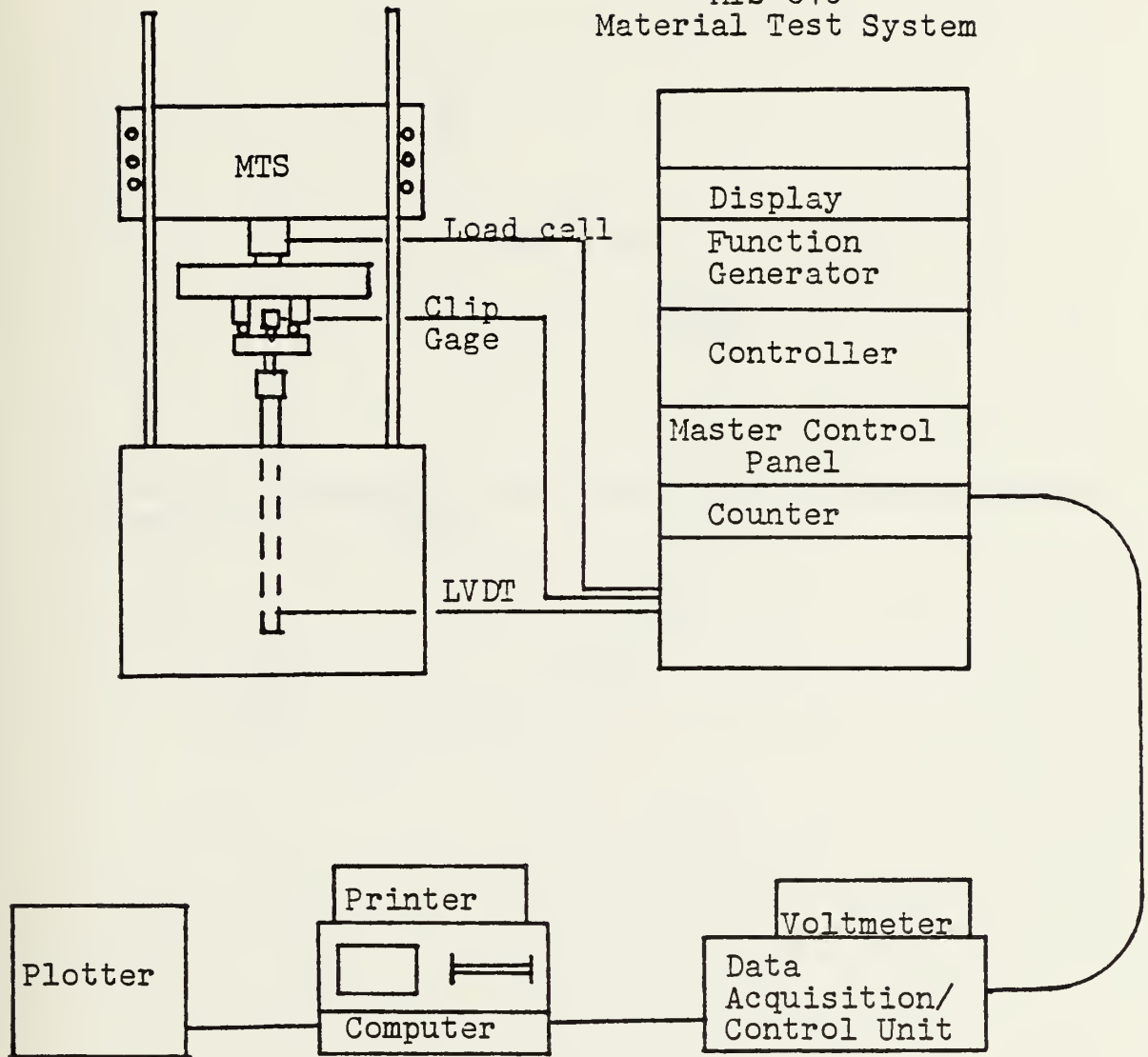


Figure 1. System Layout

J-Integral

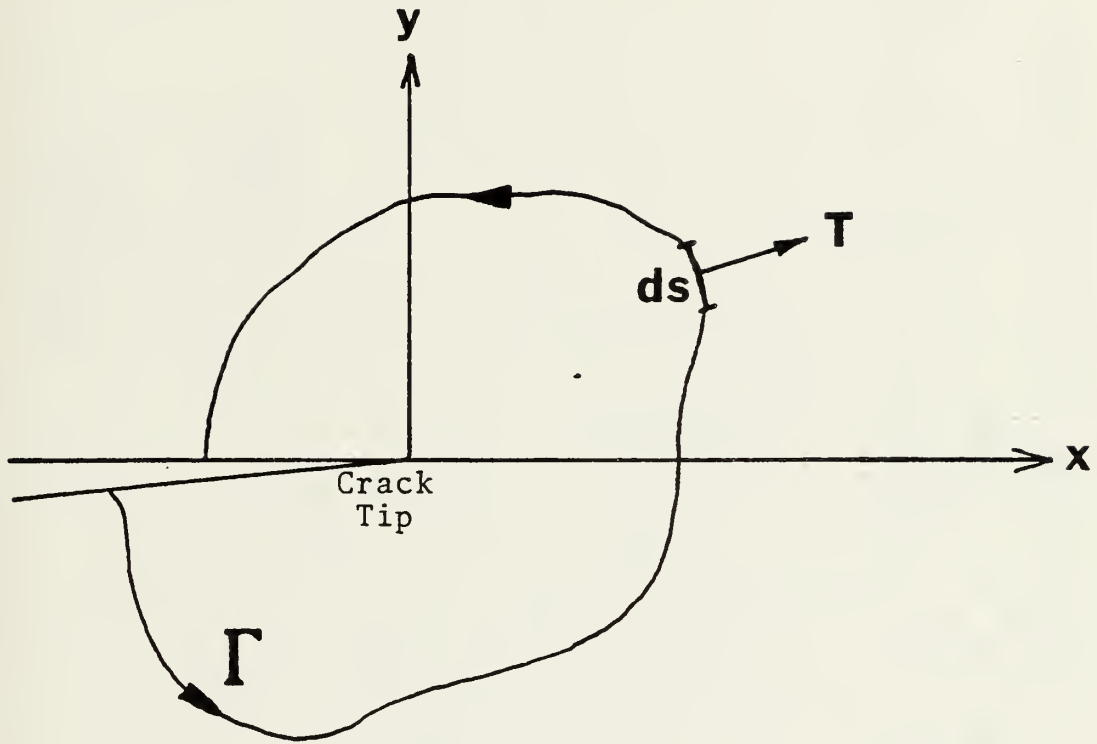


Figure 2. Pictorial Representation of J-Integral

PLOT of J vs CRACK EXTENSION for HY80-5B

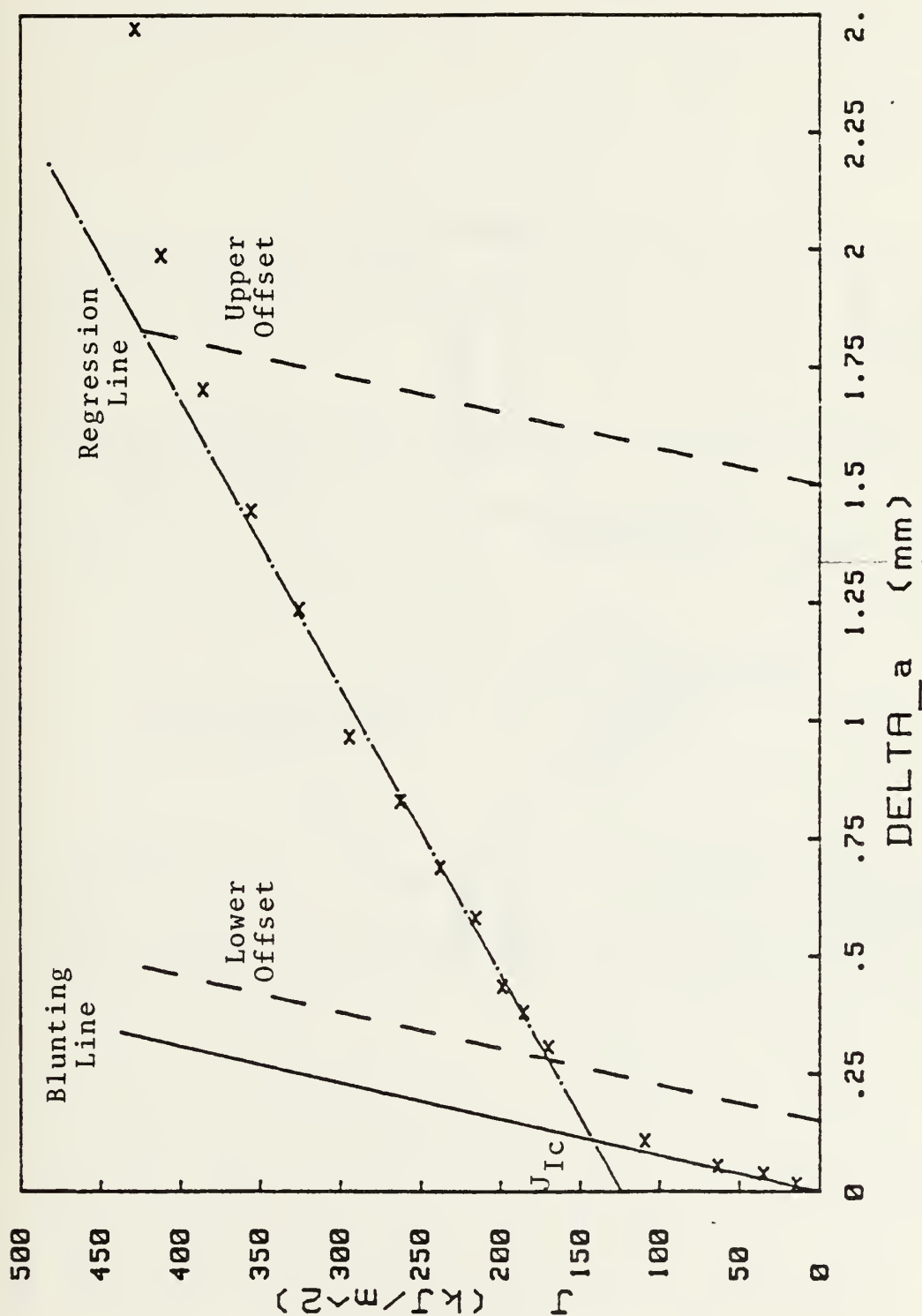


Figure 3. J Versus Crack Extension for HY80-5B

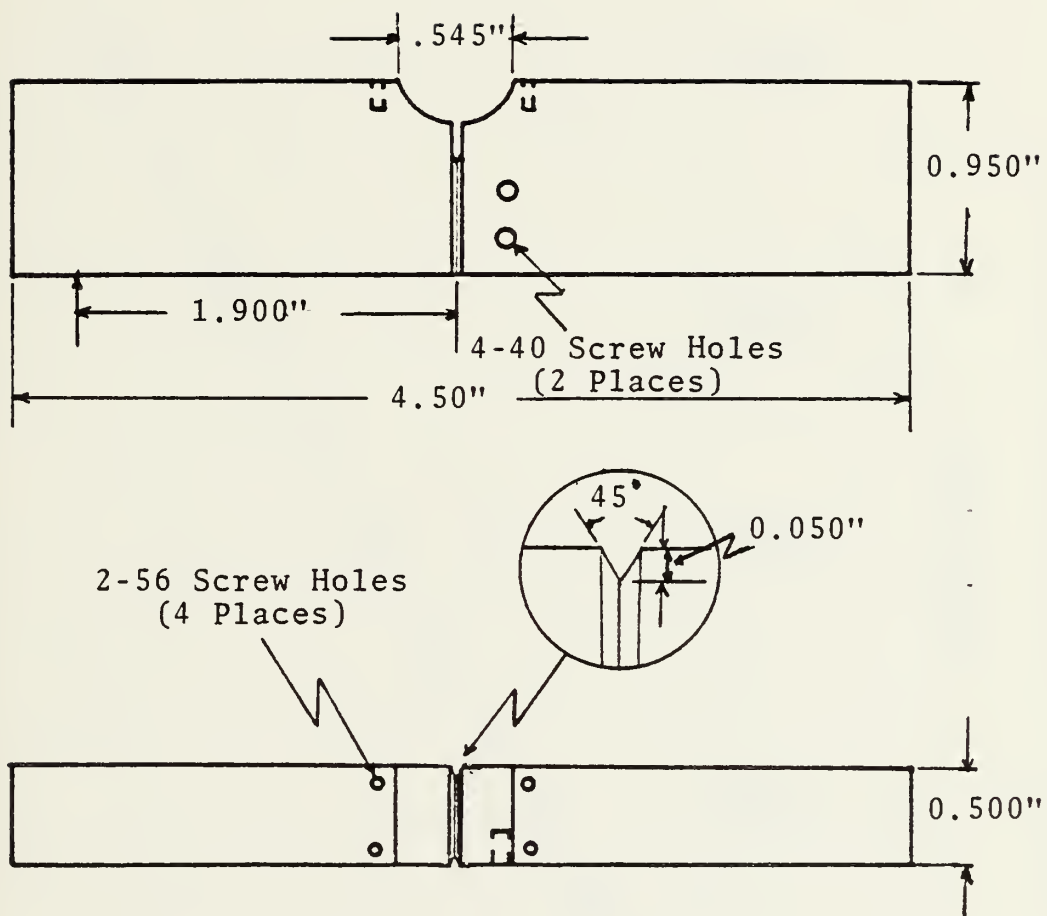


Figure 4. Specimen Drawing

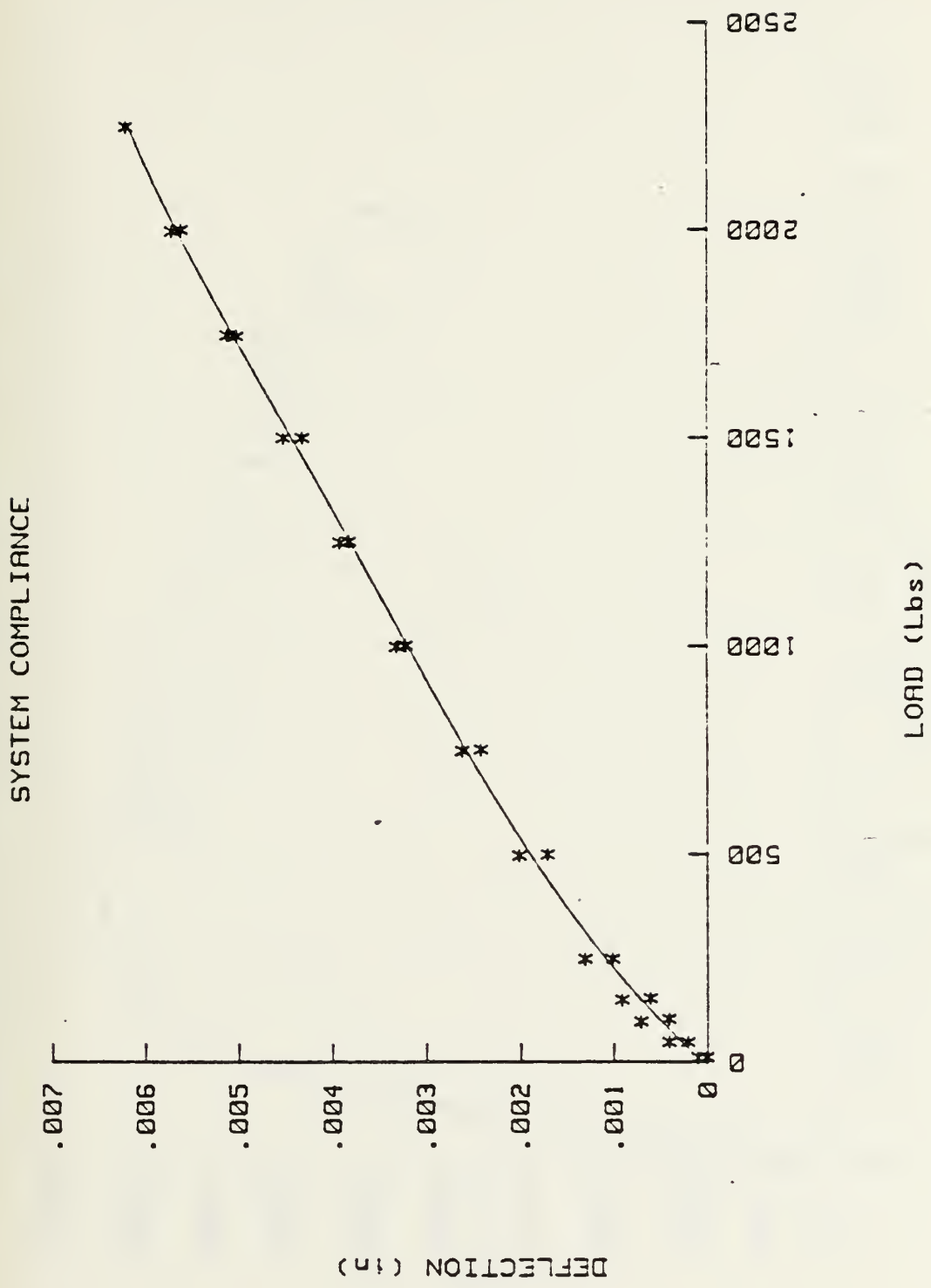


Figure 5. Plot of System's Compliance

PLOT of LOAD vs COD for HY80-5B

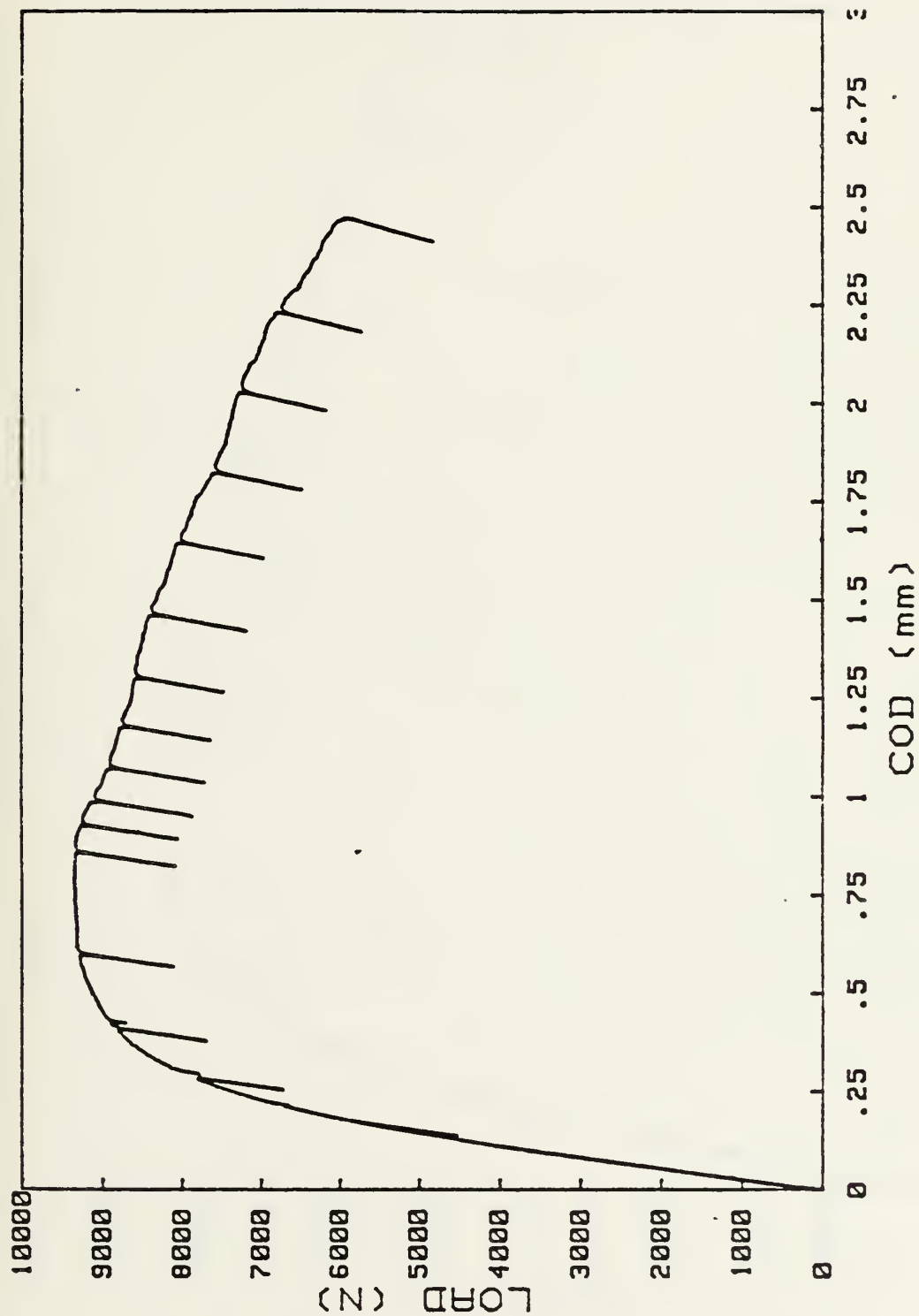


Figure 6. Plot of Load Versus COD for HY80-5B

PLOT of LOAD vs DEFLECTION for HY80-5B

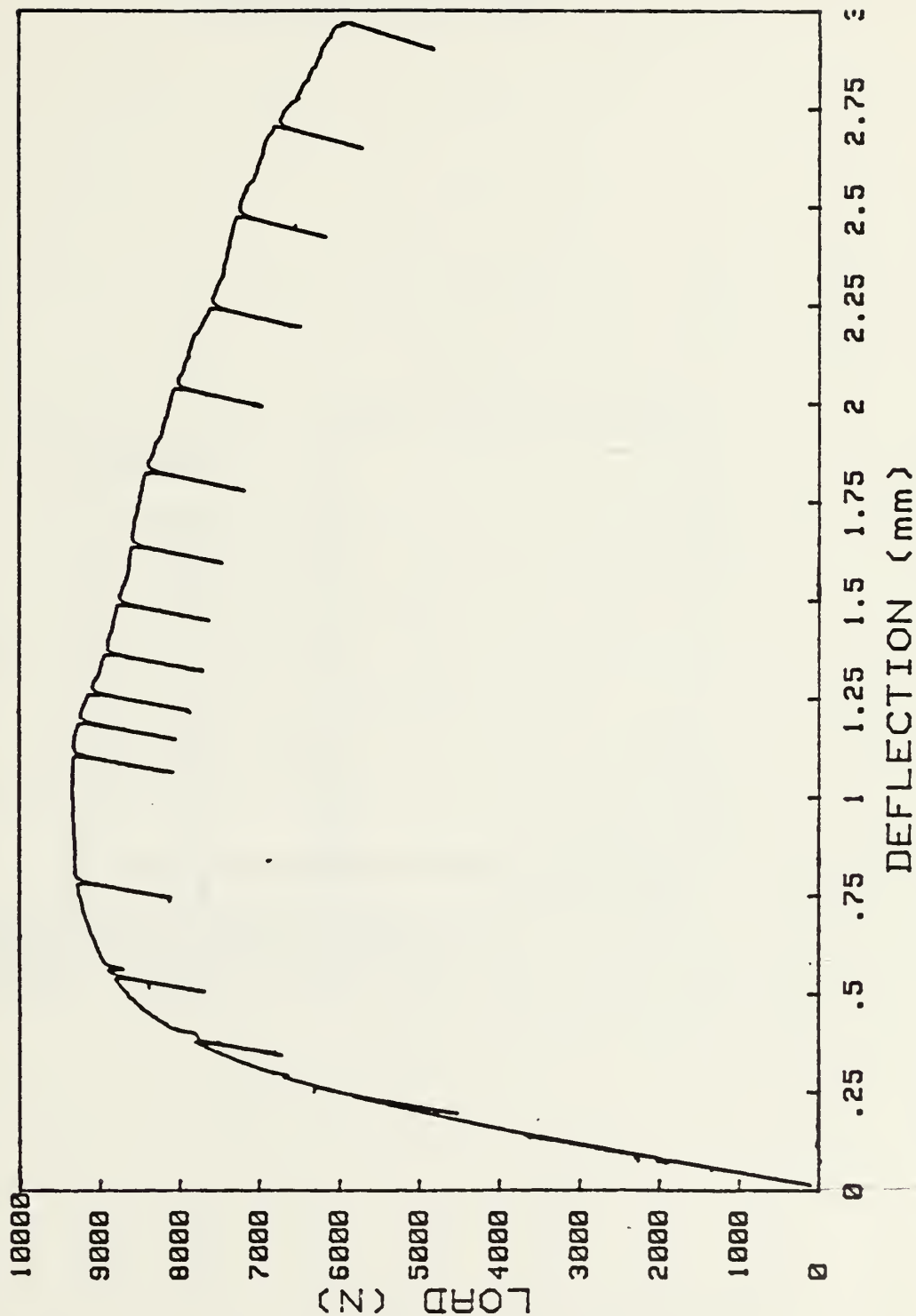


Figure 7. Plot of Load Versus Deflection for HY80-5B

Fracture Surface

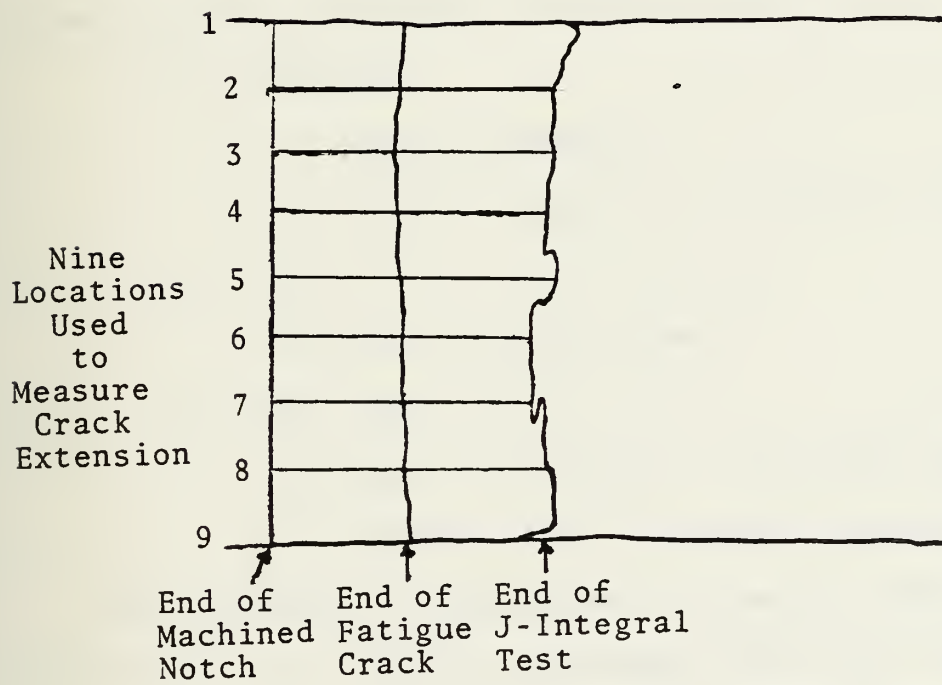


Figure 8. Tracing of HY80-5B Fracture Surface

APPENDIX A

TESTING METHODS

A. INTRODUCTION

The steps required to perform a J-integral test using a single specimen approach can be divided into three major categories, pre-test, test, and post test. Each of these categories may be further divided as shown below.

1. Pre-test

- a. Machine specimen
- b. Precrack specimen by fatigue loading

2. Test

- a. Run J-integral test

3. Post-test

- a. Heat tint specimen and break apart
- b. Measure crack extension and verify results

Each process is described in greater detail in this appendix. A working knowledge of the equipment is presupposed and awareness of all safety precautions is required before operating the MTS.

B. PRE-TEST

a. Machine Specimen

ASTM Standard E813-81 provides very specific guidance on specimen dimensions. All dimensions are related to the

width (W). Fatigue precracking is enhanced if the radius at the tip of the notch is kept to approximately 0.003 inches. This was accomplished by machining with a special cutter which was used to make only the final passes in the notch. Figure 2 can be consulted for the actual dimensions used to machine the specimens used in this work.

b. Precracking

The following step by step guide is provided to assist operators.

1. Before turning on the MTS machine ensure the proper range card is installed in the strain signal conditioner for the clip gage to be used.

2. Turn on power to all equipment with the computer being switched on last.

3. Load and run "PRECRACK" program on the HP-9826 computer.

4. Select range scales on MTS;

example: 10 v = 4000 lbs 20% of full load (range #3)

10 v = 0.02 in 10% of full clip gage (range #4)

10 v = 2.5 in 50% of full stroke (range #2)

5. Press k0-key on computer and enter specimen data as requested.

6. Press k2-key and enter conversion data as requested.

7. Press k5-key to obtain a table of COD readings for various loads and crack lengths.

8. Set READOUT knobs on the MTS Controller to be:

top = load

middle = strain

bottom = stroke

Set all to (+) polarity. See Figure A1. This ensures channels of the MTS machine are properly aligned with the data acquisition system.

9. Set MTS limit detector switches based on the information just generated by the program. Limit switch settings are determined by the simple formula:

$$\text{Limit switch} = L * 10 / \text{FSR}$$

where

L = desired limit in English units

FSR = full scale range of current operating
being used in English units

example "PRECRACK" determined:

Pmax = 1668 lbs set load limit to 1600 lbs
for specimen HY80-5B

load limits:

upper limit --- small positive load for example 40 lbs

(should never be positive)

$$+40 \text{ lbs} * 10 \text{ v} / 4000 \text{ lbs} = +0.1 \text{ v}$$

therefore set upper limit knob to +0.1 v

lower limit --- 1600 lbs maximum load

$$-1600 \text{ lbs} * 10 \text{ v} / 4000 \text{ lbs} = -4.0 \text{ v}$$

therefore set lower limit knob to -4.0 v

strain limits:

upper limit --- 0.01 in beyond maximum expected during
precracking

$$+0.01 \text{ in} * 10 \text{ v} / 0.02 \text{ in} = +5.0 \text{ v}$$

lower limit --- some small value for example -0.1 v

(should never be negative)

stroke limits:

upper limit --- 1.5 in to allow clearance for installing
specimen and yet stop the MTS if this
limit is reached

$$+1.5 \text{ in} * 10 \text{ v} / 2.5 \text{ in} = +6.0 \text{ v}$$

lower limit --- 0.25 in of compressive actuator movement
is more than sufficient for precracking

$$-0.25 \text{ in} * 10 \text{ v} / 2.5 \text{ in} = -1.0 \text{ v}$$

10. Adjust the upper roller supports as required to obtain a
span-to-width ratio (S/W) of 4.0.

11. Install specimen (with the clip gage already installed)
using alignment collars to properly center.

12. Zero the load and strain voltages.

13. Reset and clear all limit switches (all green lights on
controller panel should be showing).

14. Using load control energize hydraulics and apply a low
(<100 lbs) compressive load to the specimen by SLOWLY
turning the SETPOINT knob counter-clockwise.

15. Slowly decrease the compressive load on the specimen to between 5 and 10 lbs by turning the SETPOINT knob clockwise and then zero the stroke voltage reading.

YOU ARE NOW READY TO OBTAIN AN UNLOADING COD COMPLIANCE

MEASUREMENT OF THE CRACK LENGTH

16. Press k4-key on the computer and proceed with taking data.

17. Slowly, and as smoothly as possible increase the load to approximately 500 lbs and return to approximately 20 lbs ending the loading cycle with a slight (10 lbs) increase to trip the computer out of the data-taking loop.

The computer will display all pertinent crack length information and ask if you want another measurement. You may repeat this process as often as you like, just be sure the maximum load is lower than that required to extend the crack.

18. Make necessary adjustments to the MTS such that the strain limit switch will trip the MTS when the crack extends to 50% of the desired extension. This is determined by interpolating results from the table obtained earlier. (See Step 7).

NOTE: As the crack propagates the acceptable maximum load decreases. For the specimen, HY80-5B, used to test this program a $P_{max} = 1000$ lbs was suitable to initiate the crack and propagate it to 50% of the desired extension ($a = 0.506$ in).

Example:

50% crack extension = crack length (a) of 0.506 in
from table:

COD = 1.7 volts at 1000 lbs and a = 0.506 in

Therefore set UPPER STRAIN LIMIT SWITCH to +1.7 v.

YOU ARE NOW READY TO BEGIN CYCLIC LOADING

19. Setup MTS:

DISPLAY:

- a. Setup to read maximum and minimum load in lbs.

FUNCTION GENERATOR:

- a. CONTROL MODE: Remote
- b. RATE 1: 10 Hz
- c. RATE 2: N/A
- d. HOLD BUTTON: In
- e. BREAKPOINT: N/A
- f. HAVER SINE: In
- g. INVERT: In

CONTROLLER :

- a. SPAN 1: 0.0
- b. SPAN 2: 0.0

COUNTER:

- a. COUNTER INPUT: Oscillator
- b. COUNTER MULTIPLIER: X100
- c. Press RESET

20. Slowly increase the SETPOINT to P_{min}.

21. Press the RUN button on the CONTROLLER and then release the HOLD button of the FUNCTION GENERATOR.

22. Slowly increase the span of the cyclic loading using SPAN 1 knob to the desired P_{max}.

The MTS will continue cyclic loading until it is manually stopped or a limit detector is tripped. Most likely the COD limit detector will trip at which time the machine will stop and unload the specimen.

23. A new crack length measurement can now be obtained using the same manual process as described in Step 16 and Step 17.

24. Readjust limit switches and resume fatigue loading as done in Steps 18 through 22.

25. Continue this process until the crack reaches the desired length.

C. J-INTEGRAL TEST

The following steps are required to run a J-integral test. They are very similar to those used in precracking. The major change is that a ramp function under stroke control is now used to control the MTS machine.

1. Before turning on the MTS machine ensure the proper range card is installed in the strain signal conditioner for the clip gage to be used.

2. Turn on power to all equipment with the computer being switched on last.

3. Load and run "J_INTGL" program on the HP-9826 computer.

4. Select range scales on MTS;

example: 10 v = 4000 lbs 20% of full load (range #3)

10 v = 0.02 in 10% of full clipage (range #4)

10 v = 0.5 in 10% of full stroke (range #2)

5. Press k0-key on computer and enter specimen data as requested.
6. Press k1-key and enter conversion data as requested.
7. Press k3-key and follow instructions for creating a data file on an initialized data diskette. See HP-Mannual on how to initialize a diskette if necessary.
8. Press k3-key to setup the plotter.
9. Press k5-key and obtain the maximum load you may apply while measuring a0.

YOU ARE NOW READY TO SETUP THE MTS MACHINE

10. Set READOUT knobs on the MTS Controller to be:

top = load

middle = strain

bottom = stroke

Set all to (+) polarity. See Figure A1.

11. Set MTS limit detectors switches.

example:

Pmax = 895 lbs for HY80-5B (see Appendix H)

load limits:

upper limit --- small positive load (40 lbs)

(should never be positive)

+40 lbs * 10 v / 4000 lbs = +0.1 v

lower limit --- 895 lbs compression maximum

-895 lbs * 10 v / 4000 lbs = -2.125 v

strain limits:

upper limit --- want to be able to read full scale
on range #2 (0.1 in)

$$+0.1\text{in} * 10 \text{ v} / 0.1 \text{ in} = +10 \text{ v}$$

lower limit --- a very small value set to -0.1 v
(should never be negative)

stroke limits:

upper limit --- full scale (+10.0 v) on this most
sensitive scale

lower limit --- a maximum compression of 0.25 in is
sufficient for the test and will stop
the actuator before it can cause any
serious damage to the specimen holder

$$-0.25 \text{ in} * 10 \text{ v} / 0.5 \text{ in} = -5.0 \text{ v}$$

12. Adjust the upper roller supports as required to obtain a
span-to-width ratio of 4.0.

13. Install the specimen (with the clip gage already
installed) using the alignment collars to properly center.

14. Zero the load and strain voltages.

15. Reset and clear all limit switched (all green lights on
controller panel should be showing).

16. Using load control energize hydraulics and apply a low
(<100 lbs) compressive load to the specimen by SLOWLY
turning the SETPOINT knob counter-clockwise.

17. Decrease the load to between 5 and 10 lbs and zero the
stroke voltage.

18. Adjust the MTS to the following settings:

DISPLAY:

- a. Setup to read load in lbs and stroke in inches.

FUNCTION GENERATOR:

- a. CONTROL MODE: Remote
- b. RATE 1: 6000 (sec)
as determined by: desire 0.005 in/min loading rate
therefore;

$$0.5 \text{ in (full scale)} / 0.005 \text{ in/min} * 60 \text{ sec/min} = 6000 \text{ sec}$$

- c. RATE 2: N/A
- d. HOLD BUTTON: In
- e. BREAKPOINT: N/A
- f. RAMP BUTTON: In
- g. INVERT: IN

CONTROLLER:

- a. SPAN 1: 10.0 (full scale)
- b. SPAN 2: 0.0

COUNTER: N/A

YOU ARE NOW READY TO MEASURE THE INITIAL CRACK LENGTH

19. The computer will begin taking data after the 'CONTINUE' key is pressed. The MTS will begin loading the specimen after the MTS' RUN switch is pressed and the HOLD button is released.

20. When the desired maximum load (approximately 500 lbs) is reached; depress the HOLD button, switch to load control, and manually decrease the load (to approximately 20 lbs) by SLOWLY turning the SETPOINT knob clockwise. As with precracking you must end the unloading with a small increase in load (10 lbs from where you stop) to signal the computer you have completed the load/unload cycle. The computer will

plot the data as you go, ensure you remain on the linear portion of the loading curve.

21. The computer will display all the pertinent crack length information. You may repeat this operation by switching back to stroke control and repeating Steps 19 and 20 as often as you like as long as you remain on the linear portion of the loading curve.

22. After the computer has stored the desired initial crack length (a_0) measurement on data diskette, you are ready to begin propagating the crack.

23. Ensure you are in stroke control with near zero (<10 lbs) load and the RUN light is on with the HOLD button depressed.

24. Press the k7-key on the computer follow instructions and proceed to collecting data (data acquisition system will be continuously switching channels and the plotter will be plotting), now release the HOLD button on the MTS.

25. When you reach a point where you wish to unload the specimen; press the HOLD button, switch to load control, and slowly decrease the load. The computer will beep when you have unloaded the specimen by 10% of the expected maximum load. Switch back to stroke control and release the HOLD button to reload the specimen.

26. When the load returns to the point from which the unloading began the computer will display and printout all

the information it has determined with regards to the current unloading cycle.

27. This process of switching control modes (Steps 25 and Step 26) are repeated for every unloading cycle until the you decide to stop by pressing the k9-key on the computer or one of the limit detectors shuts off the MTS machine. Remember, you must have atleast four data points between the offsaets one of which lies near the blunting line on the J-R curve.

28. The k9-key interrupts the computer program and tells it to stop taking data and write the data it has collected on the data diskette.

29. The computer will then display a table of the collected J versus delta_a and ask if you desire a plot. Simply follow the directions from the computer and you will obtain the J-R curve and the value of J_{IC} .

D. POST-TEST

The post-test includes verifying the final crack length, and validating the other parameters as discussed in ASTM Standard E813-81 such as:

$$b_1 \text{ and } B_{min} > 25 * J_{IC} / F_s$$

where

b_1 = uncracked ligament after precracking

B_{min} = minimum specimen thickness

F_s = flow stress

and that the slope of the linear regression fit to the data is less than the flow stress ($dJ/da < F_s$). This data is obtained directly from the "J_INTGL" program output.

Heat tinting the specimen, 10 minutes at 300C for most steels, aids in the visual identification of the amount of crack extension. After the specimen is removed from the oven and air cooled, place it in liquid nitrogen to assist in obtaining a brittle fracture. After breaking the specimen apart, place the pieces in alcohol while returning to room temperature. This will prevent water vapor from condensing and freezing on the surface and minimize oxidation.

A photographic enlargement of the surface can now be obtained and the crack length can easily be verified. The final crack extension must be within 15% of that recorded during the test.

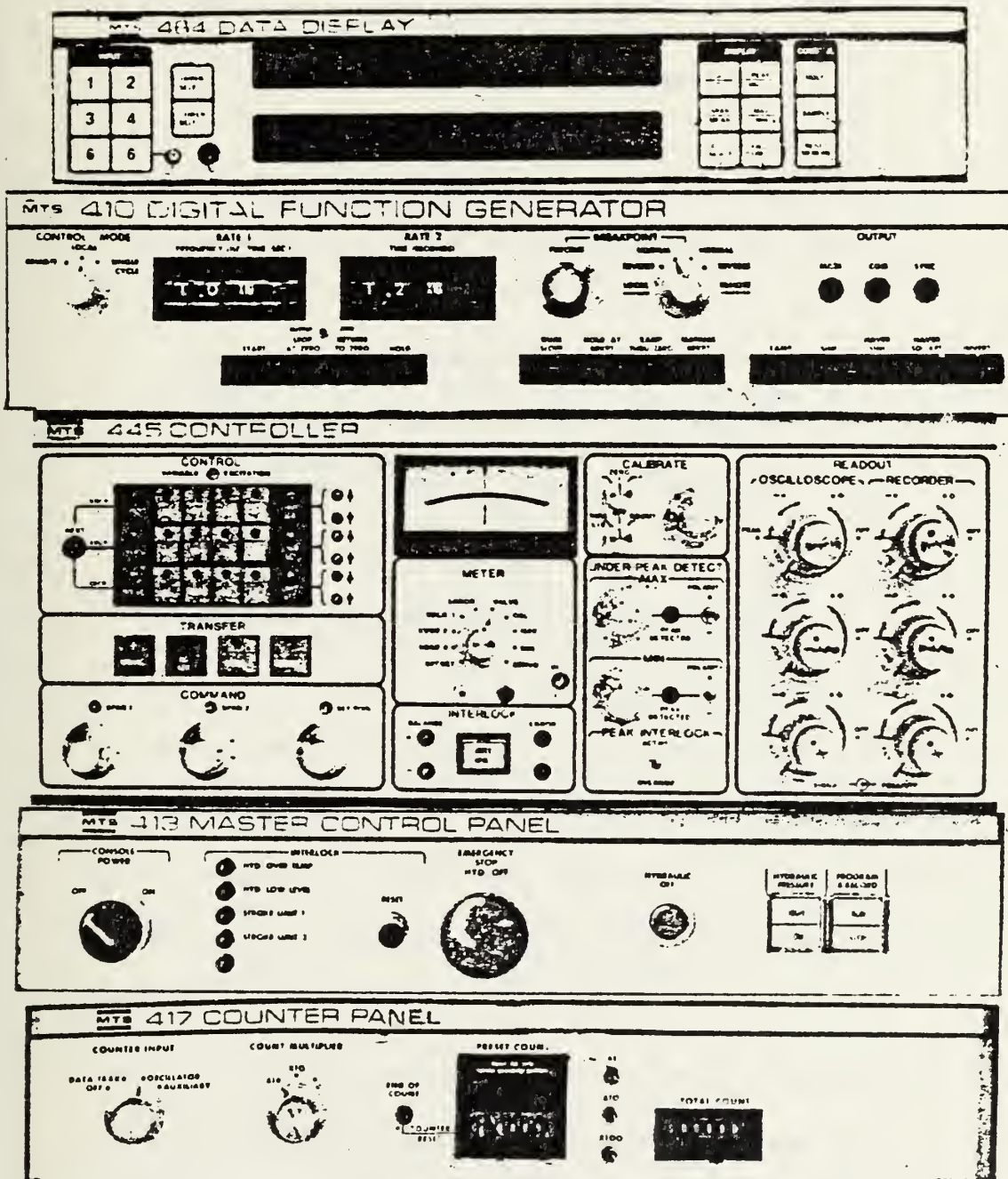


Figure A1. MTS Control Panel

APPENDIX B

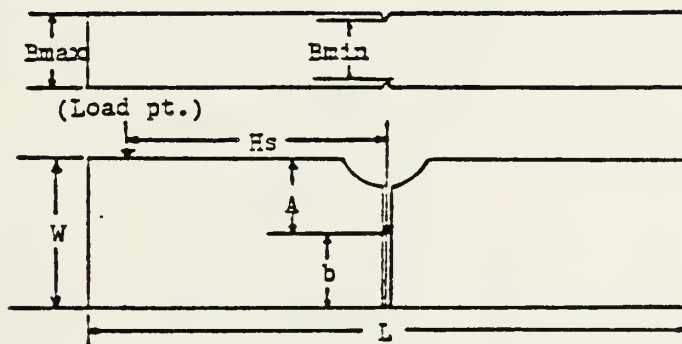
TEST RECORD SHEET

THREE POINT BEND SPECIMEN

TEST REPORT

SPECIMEN I.D. _____ MATERIAL _____ ORIENTATION _____

Date _____ Operator _____ Test Temp _____



$W =$ _____ $A =$ _____ $b =$ _____ $L =$ _____

$H_s =$ _____ $B_{max} =$ _____ $B_{min} =$ _____

$Y_s =$ _____ $U_s =$ _____ $F_s =$ _____

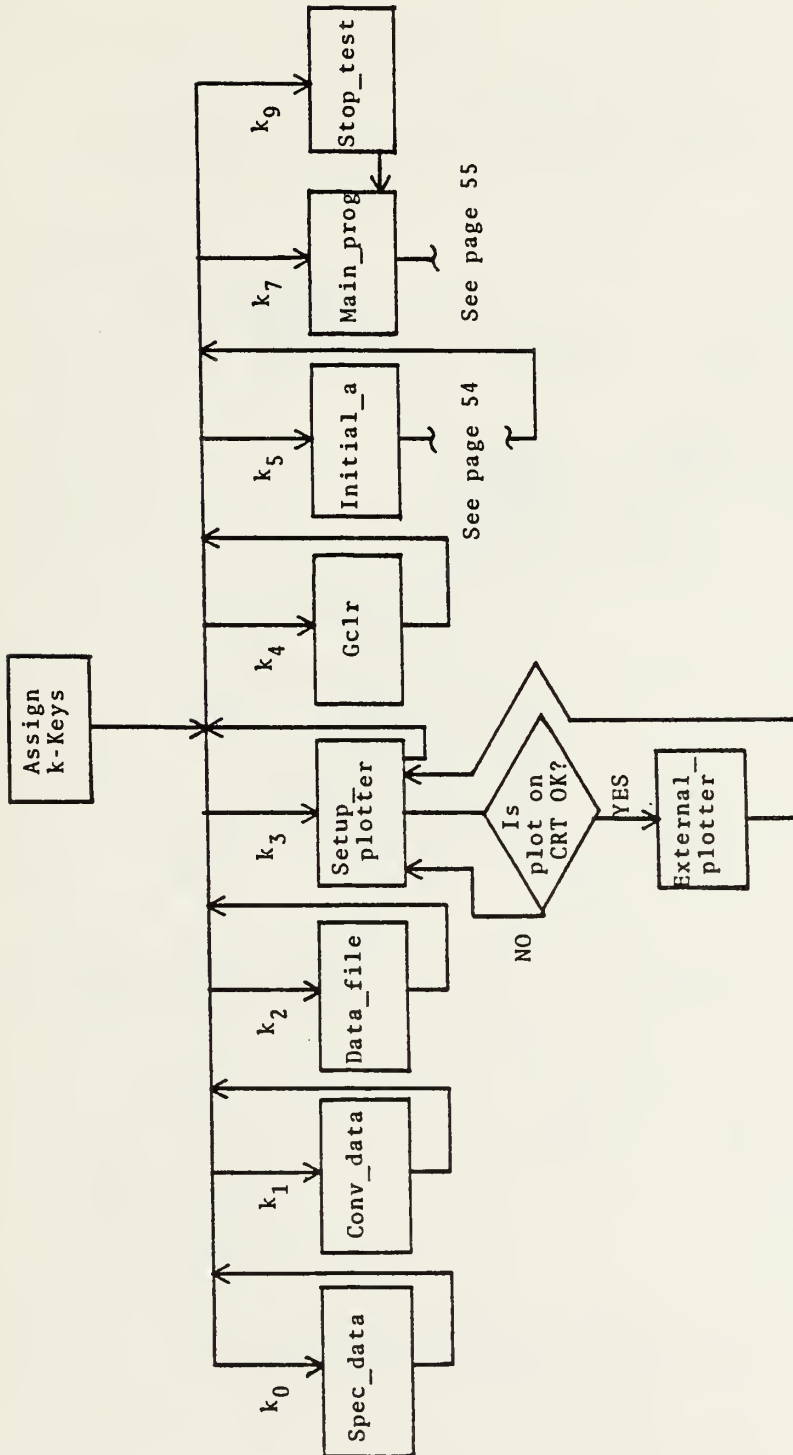
Poisson's ratio = _____ Elastic Modulus = _____

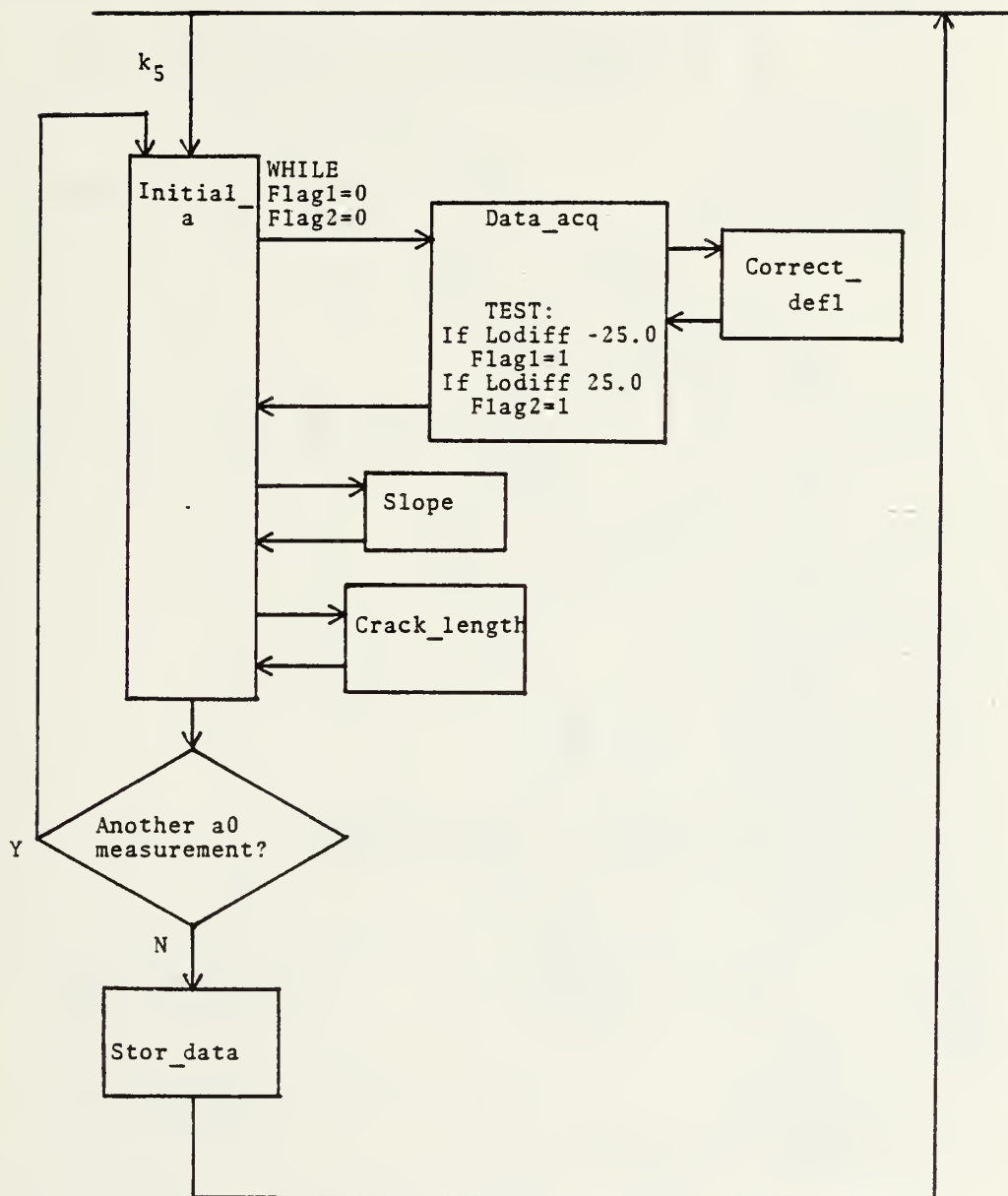
Comments:

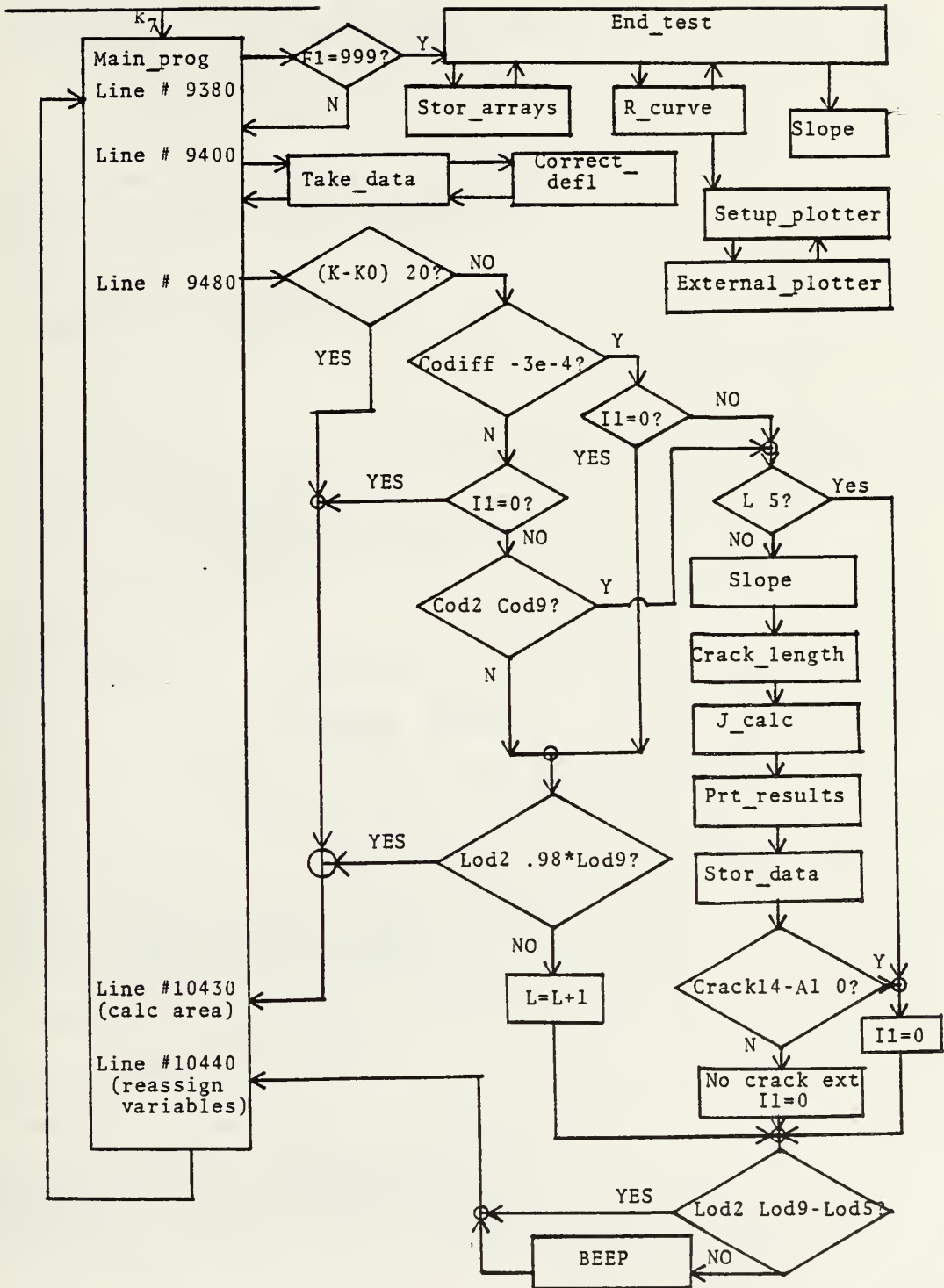
APPENDIX C

J_INTGL FLOW CHART

"J_INTGL" FLOW CHART







APPENDIX E

PRECRACK LISTING

```
10 ! PRECRACKING PROGRAM FOR THREE POINT
20 ! BEND SPECIMEN. THIS PROGRAM INCORPORATES
30 ! THE USE OF THE FOLLOWING EQUIPMENT:
40 !     1. HP-9826 COMPUTER
50 !     2. HP-3497A DATA ACQUISITION SYSTEM
60 !     3. HP-2671G THERMAL PRINTER
70 !     4. MTS MACHINE
80 !
90 ! THE PROGRAM USES BOTH ENGLISH AND METRIC
100 ! UNITS. ALL METRIC VARIABLES ARE DENOTED
110 ! WITH AN m IN THEIR NAME ie Wm=WIDTH IN
120 ! METRIC UNITS (mm IN THIS CASE).
130 !
140 ! THIS PROGRAM WAS WRITTEN BY:
150 !     LCDR W. K. TRITCHLER, USN
160 ! VERSION 1.0     DATE 11/83
170 !
180 !
190 !
200 COM /J_intgl/ FI
210 !
220 ! DIM Lodm(2000),Deflm(2000),Codm(2000) these arrays will be dimensioned
230 ! required in the New_a routine.
240 ! Lodm(I) = LOAD IN NEWTONS
250 ! Deflm(I) = DEFLECTION IN mm
260 ! Codm(I) = CRACK OPENING DISPLACEMENT IN mm
270 !
280 DIM Coef(6),G(6),A0(100)
290 DUMP DEVICE IS 706
300 Dvm=709
310 CLEAR Dvm
320 PRINT CHR$(12)      ! CLEARS CRT
330 PRINT ""
340 PRINT "      PRECRACKING PROGRAM"
350 PRINT "      VERSION 1.0"
360 PRINT ""
370 PRINT "      WRITTEN BY LCDR W.K. TRITCHLER"
380 PRINT ""
390 PRINT "      PLEASE SELECT A k-KEY"
400 !
410 !*****
420 Begin: !
430 ON KEY 0 LABEL "SPEC_DATA" GOSUB Spec_data
440 ON KEY 2 LABEL "CONV_DATA" GOSUB Conv_data
450 ON KEY 4 LABEL "NEW_A" GOSUB New_a
460 ON KEY 5 LABEL "a_TABLE" GOSUB A_table
470 !
480 !*****
490 !
500 Spin: ! WAITS FOR KEY INPUT
510 GOTO Spin
520 !
530 !*****
540 !
550 Spec_data: ! INPUTS REQUIRED SPECIMEN DATA
560 PRINT CHR$(12)      ! CLEARS CRT
570 PRINT "INPUT SPECIMEN IDENTIFICATION (ID):"
580 INPUT Ds
590 PRINT ""
```



```

600 PRINT "J-INTEGRAL TEST for ";Ds
610 PRINT ""
620 PRINT "INPUT SPECIMEN DATA USING ENGLISH UNITS (LBS.      INCHES, etc.)"
630 PRINT ""
640 PRINT "WHAT IS THE SPECIMEN'S WIDTH, NOTCH LENGTH, Bmax, Bmin (THICKNESS)
    ?"
650     INPUT W,A,Bmax,Bmin
660     PRINT ""
670 PRINT "WHAT IS THE SPECIMEN'S HALF SPAN AND POISSON'S      RATIO?"
680     INPUT Hs,Nu
690 PRINT ""
700 PRINT "WHAT IS THE SPECIMEN'S ELASTIC MODULUS, YIELD      STRENGTH AND ULT
IMATE STRENGTH?"
710     INPUT E,Ys,Uts
720 PRINT CHR$(12)          ! CLEARS CRT
730 Fs=(Ys+Uts)/2
740 PRINT "USING ENGLISH UNITS (in.lbs.psi)"
750 PRINT "THE FOLLOWING HAS BEEN ENTERED for: ";Ds
760 PRINT "WIDTH =";W;"      NOTCH LENGTH =";A
770 PRINT "Bmax =";Bmax;"      Bmin =";Bmin
780 PRINT "HALF SPAN =";Hs;"    POISSON'S RATIO =";Nu
790 PRINT "YIELD STRENGTH =";Ys;"    ULTIMATE TS =";Uts
800 PRINT "ELASTIC MODULUS =";E;"    FLOW STRESS =";Fs
810 PRINT ""
820 PRINT "THIS PROGRAM ALLOWS NO EASY RECOVERY, IF ANY DATA IS INCORRECT YOU
MUST RE-ENTER ";
830 PRINT "EVERYTHING."
840 PRINT ""
850 PRINT "IS ALL DATA CORRECT?"
860 INPUT Hs
870 IF Hs="NO" OR Hs="N" THEN 550    ! REPEATS Spec_data
880 PRINT ""
890 PRINT "DO YOU WANT A HARD COPY?"
900 INPUT Hs
910 IF Hs="N" OR Hs="N" THEN 1060
920 !
930 PRINTER IS 706          ! TOGGLES PRINTER TO THERMAL PRINTER
940 PRINT ""
950 PRINT "USING ENGLISH UNITS (in.lbs.psi) THE FOLLOWING INFORMATION"
960 PRINT "HAS BEEN ENTERED FOR: ";Ds
970 PRINT ""
980 PRINT "WIDTH =";W;"      NOTCH LENGTH =";A
990 PRINT "Bmax =";Bmax;"      Bmin =";Bmin
1000 PRINT "HALF SPAN =";Hs;"    POISSON'S RATIO =";Nu
1010 PRINT "YIELD STRENGTH =";Ys;"    ULTIMATE TS =";Uts
1020 PRINT "ELASTIC MODULUS =";E;"    FLOW STRESS =";Fs
1030 PRINT ""
1040 PRINTER IS 1          ! TOGGLES PRINTER BACK TO CRT
1050 !
1060 PRINT CHR$(12)        ! CLEARS CRT
1070 !
1080 ! CONVERSION TO METRIC UNITS
1090 Conlen=25.4          ! 1in = 25.40mm
1100 Wm=W*Conlen
1110 Am=A*Conlen
1120 Bmaxm=Bmax*Conlen
1130 Bminm=Bmin*Conlen
1140 Hsm=Hs*Conlen
1150 Conpress=6.89475293    ! 1psi = 6.89475293kPa (HP PROGRAMING BOOK)
1160 Em=E*Conpress

```



```

1170 Ysm=Ys*Conpress
1180 Utsm=Uts*Conpress
1190 Fsm=Fs*Conpress
1200 !
1210 PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) for ";Ds;" YIEL
DS:"
1220 PRINT "WIDTH =";Wm;" NOTCH LENGTH =";Am
1230 PRINT "Bmax =";Bmaxm;" Bmin =";Bminm
1240 PRINT "HALF SPAN =";Hsm;" POISSON'S RATIO =";Nu
1250 PRINT "YIELD STRENGTH =";Ysm;" ULTIMATE TS =";Utsm
1260 PRINT "ELASTIC MODULUS =";Em;" FLOW STRESS =";Fsm
1270 PRINT ""
1280 PRINT "DO YOU WISH TO HAVE A PRINT OUT OF THIS DATA?"
1290 INPUT G$
1300 IF G$="N" OR G$="NO" THEN 1410
1310 !
1320 PRINTER IS 706 ! TOGGLES TO THERMAL PRINTER
1330 PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: ";Ds
1340 PRINT "WIDTH =";Wm;" NOTCH LENGTH =";Am
1350 PRINT "Bmax =";Bmaxm;" Bmin =";Bminm
1360 PRINT "YIELD STRENGTH =";Ysm;" ULTIMATE TS =";Utsm
1370 PRINT "ELASTIC MODULUS =";Em;" FLOW STRESS =";Fsm
1380 PRINT ""
1390 PRINTER IS 1 ! TOGGLES PRINTER TO CRT
1400 !
1410 PRINT CHR$(12) ! CLEAR CRT
1420 !
1430 Flag3=0
1440 A1=A
1450 GOSUB Params
1460 !
1470 RETURN
1480 !
1490 !*****
1500 !
1510 New_a: ! THIS ROUTINE COMPUTES NEW CRACK LENGTH AND NEW PARAMETERS
1520 !
1530 Beffm=Bmaxm-(Bmaxm-Bminm)^2/Bmaxm ! B EFFECTIVE FROM ASTM E813-81
1540 D2=1 ! INITIALIZES COUNTER
1550 PRINT CHR$(12) ! CLEARS CRT
1560 PRINT "THIS ROUTINE WILL OBTAIN CURRENT CRACK LENGTH"
1570 PRINT " AND NEW PARAMETERS FOR PRECRACKING."
1580 PRINT "BEFORE YOU CAN RUN THIS ROUTINE YOU MUST:"
1590 PRINT " 1. ENTER SPECIMEN DATA"
1600 PRINT " 2. ENTER CONVERSION DATA"
1610 PRINT " 3. SETUP MTS FOR MANUAL LOADING OF THE";
1620 PRINT " SPECIMEN."
1630 PRINT ""
1640 PRINT " ARE YOU READY?"
1650 INPUT H$
1660 IF H$="N" OR H$="NO" THEN 2450 ! RETURNS TO k-KEY SELECTION
1670 PRINT CHR$(12) ! CLEARS CRT
1680 PRINT "YOU MAY LOAD AND UNLOAD SPECIMEN AS OFTEN AS YOU LIKE -- BUT YOU M
UST REMAIN ";
1690 PRINT "BELOW CURRENT PMAx OF";Pmax;"Lbs"
1700 DIM Lod(2000),Def1(2000),Cod(2000)
1710 DIM Lodm(2000),Def1m(2000),Codm(2000)
1720 PRINT "WHEN YOU ARE READY TO BEGIN PRESS THE 'ENTER' OR 'CONTINUE' KEY."
1730 INPUT H$
1740 PRINT CHR$(12) ! CLEARS CRT

```



```

1750 K=0 ! USED AS COUNTER
1760 I=1 ! USED AS INDEX
1770 Flag1=0
1780 Flag2=0
1790 WHILE Flag1=0 ! ESTABLISHES ONE LOAD-UNLOAD DATA TAKING LOOP
1800 GOSUB Data_acq
1810 END WHILE
1820 Flag2=0 ! RESETS FLAG2
1830 WHILE Flag2=0
1840 GOSUB Data_acq
1850 END WHILE
1860 !
1870 ! THIS SECTION CAN BE USED TO VIEW THE COLLECTED DATA BY REMOVING THE REMA
RK CHARACTER (!).
1880 ! FOR I=1 TO K
1890 ! PRINT USING 1960;I,Lodm(I),Deflm(I),Codm(I)
1900 ! IMAGE X,3D,4X,6D.D,4X,3D,7D,7X,3D,7D
1910 ! NEXT I
1920 ! WAIT 5
1930 K1=1
1940 K3=K
1950 GOSUB Slope ! SLOPE = 1/COD COMPLIANCE
1960 GOSUB Crack_length ! USES COD COMPLIANCE
1970 !
1980 A0(D2)=Cracklm/25.4 ! CONVERTS TO INCHES
1990 A1=A0(D2)
2000 !
2010 ! FIND 95% CONFIDENCE INTERVAL FOR CRACK LENGTH
2020 Stiffm=Stiffm+T9*U4
2030 GOSUB Crack_length
2040 Amax=Cracklm/25.4 ! CONVERTS TO INCHES
2050 Stiffm=Stiffm-2*T9*U4
2060 GOSUB Crack_length
2070 Amin=Cracklm/25.4 ! CONVERTS TO INCHES
2080 !
2090 !
2100 PRINT CHR$(12) ! CLEARS CRT
2110 PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
2120 PRINT ""
2130 PRINT "CRACK LENGTH =";A0(D2);"in FROM MEASUREMENT #";D2
2140 PRINT "WITH 95% CONFIDENCE INTERVAL FROM";Amin;" TO";Amax
2150 PRINT ""
2160 PRINT "USING COD COMPLIANCE OF";Compl;"in/Lb =";Complm;"mm/N"
2170 PRINT "WITH A CORRELATION OF";Correl;" FROM";K;"DATA POINTS"
2180 PRINT ""
2190 PRINT "DO YOU WANT A HARD COPY?"
2200 INPUT G$
2210 IF G$="N" OR G$="NO" THEN 2340
2220 !
2230 PRINTER IS 706 ! TOGGLES TO THERMAL PRINTER
2240 PRINT ""
2250 PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
2260 PRINT "CRACK LENGTH =";A0(D2);"in FROM MEASUREMENT #";D2
2270 PRINT "WITH 95%CONFIDENCE INTERVAL FROM";Amin;" TO";Amax;"in"
2280 PRINT "USING COD COMPLIANCE OF";Compl;"in/Lb =";Complm;"mm/N"
2290 PRINT "WITH A CORRELATION OF";Correl;"FROM";K;" DATA POINTS."
2300 PRINT ""
2310 PRINTER IS 1 ! TOGGLES PRINTER TO CRT
2320 !

```



```

2330 PRINT ""
2340 PRINT " DO YOU WANT ANOTHER MEASUREMENT?"
2350 INPUT F$
2360 D2=D2+1 ! INCREMENTS COUNTER
2370 IF F$="Y" OR F$="YES" THEN 1670
2380 !
2390 IF A0(D2-1)>Opta THEN GOSUB End_precrack ! PRECRACKING IS COMPLETE
2400 !
2410 IF A0(D2-1)>.4*Delta+A THEN Flag3=1 ! SETS FLAG INDICATING IN LAST 60% O
F PRECRACKING
2420 !
2430 GOSUB Params
2440 !
2450 RETURN
2460 !
2470 !*****
2480 !
2490 Data_acq: ! DATA ACQUISITION ROUTINE
2500 OUTPUT Dvm:"VRS AF1 AL3"
2510 !
2520 OUTPUT Dvm:"AI1 VT1" ! READS LOAD
2530 ENTER Dvm:Lod(I)
2540 Lodm(I)=Lod(I)*Slm(1)
2550 !
2560 OUTPUT Dvm:"AI2 VT1" ! READS COD
2570 ENTER Dvm:Cod(I)
2580 Codm(I)=Cod(I)*Slm(2)
2590 !
2600 OUTPUT Dvm:"AI3 VT1" ! READS DEFLECTION
2610 ENTER Dvm:Defl(I)
2620 Deflm(I)=Defl(I)*Slm(3)
2630 !
2640 ! TEST DATA TO BREAK OUT OF DATA ACQ LOOP
2650 !
2660 IF I=1 THEN 2720 ! SKIPS IF FIRST DATA POINT
2670 Loddiffm=Lodm(I)-Lodm(I-1)
2680 IF Loddiffm<-25.0 THEN Flag1=1 ! MUST BE UNLOADING
2690 IF Loddiffm>25.0 THEN Flag2=1 ! MUST BE RELOADING.
2700 Loddiffm=0
2710 !
2720 I=I+1 ! INCREMENTS INDEX
2730 !
2740 K=K+1 ! INCREMENT COUNTER
2750 !
2760 RETURN
2770 !
2780 !*****
2790 !
2800 Crack_length: ! CALCULATES CRACK LENGTH USING HUDAK (DTNSRDC PROG)
2810 ! NOTE: THIS ROUTINE USES COD COMPLIANCE METHOD VICE DEFLECTION COMPLIA
NCE.
2820 FOR I=1 TO 6
2830 READ Coef(I)
2840 NEXT I
2850 Complm=1/Stiffm
2860 C=2*Wm*Beffm*Em*Complm/(Hsm*1000)
2870 C=1/(SQR(C)+1)
2880 G(1)=C
2890 FOR I=2 TO 5
2900 G(I)=G(I-1)*G(1)

```



```

2910 NEXT I
2920 F=Coef(1)
2930 FOR I=1 TO 5
2940     F=F+Coef(I+1)*G(I)
2950 NEXT I
2960 CrackIn=F*Wm
2970 RESTORE
2980 DATA 0.998265,-3.81662,-1.80596,32.31038,-44.15665,-52.67876
2990 !
3000 RETURN
3010 !
3020 !*****
3030 !
3040 Conv data:      ! INPUTS CONVERSION DATA FOR MEASURING DEVICES
3050 PRINT CHR$(12)      ! CLEARS CRT
3060 PRINT "INPUT: LOAD RANGE, STRAIN RANGE, STROKE RANGE"
3070 PRINT ""
3080 PRINT "      (BY PERCENT ie. 10,20,50 OR 100)"
3090 INPUT Lr,Cr,Sr
3100 PRINT ""
3110 PRINT "LOAD RANGE = ":Lr
3120 PRINT "STRAIN (COD) RANGE = ":Cr
3130 PRINT "STROKE (DEFLECTION) RANGE = ":Sr
3140 Lmax=20000      ! MAX LOAD RANGE IN (lbs).
3150 Cmax=.200      ! MAX COD RANGE IN (in).
3160 Smax=5.0      ! MAX STROKE RANGE IN (in).
3170 V=-10      ! MAX VOLTAGE IN (volts).
3180 !
3190 ! MAXIMUM OPERATING POINTS ARE:
3200 Olmax=Lmax*Lr/100
3210 Ocmax=Cmax*Cr/100*(-1.0) ! -1 CHANGES SIGN
3220 Osmax=Smax*Sr/100
3230 !
3240 ! CONVERSION CONSTANTS ARE: (ENGLISH UNITS)
3250 Sl(1)=Olmax/V
3260 Sl(2)=Ocmax/V
3270 Sl(3)=Osmax/V
3280 ! CONVERTING TO METRIC:
3290 Conlen=25.4      ! 25.4mm = 1in
3300 Conlb=4.448221615      ! 4.448221615N = 1lb      (HP PROGRAMING BOOK)
3310 Slm(1)=Sl(1)*Conlb
3320 Slm(2)=Sl(2)*Conlen
3330 Slm(3)=Sl(3)*Conlen
3340 !
3350 PRINT ""
3360 PRINT ""
3370 PRINT "YOUR ENTRIES HAVE PRODUCED THE FOLLOWING      CONVERSION DATA:
3380 PRINT ""
3390 PRINT "FOR LOAD: ";Slm(1);"NEWTON/VOLT      (":Sl(1);"Lbs/V)"
3400 PRINT ""
3410 PRINT "FOR COD: ";Slm(2);"mm/V      (":Sl(2);"in/V)"
3420 PRINT ""
3430 PRINT "FOR DEFLECTION: ";Slm(3);"mm/V      (":Sl(3);"in/V)"
3440 PRINT ""
3450 PRINT "WOULD YOU LIKE A HARD COPY?"
3460 INPUT H$
3470 IF H$="N" OR H$="NO" THEN 3570
3480 !
3490 PRINTER IS 706      ! TOGGLES PRINTER

```



```

3500 PRINT ""
3510 PRINT "      CONVERSION DATA"
3520 PRINT "FOR LOAD:";Slm(1);"N/V      (";Sl(1);"Lbs/V)"
3530 PRINT "FOR COD:";Slm(2);"mm/V      (";Sl(2);"in/V)"
3540 PRINT "FOR DEFLECTION:";Slm(3);"mm/V      (";Sl(3);"in/V)"
3550 PRINTER IS 1      ! TOGGLES PRINTER
3560 !
3570 PRINT CHR$(12)
3580 !
3590 RETURN
3600 !
3610 !*****
3620 !
3630 Slope: ! LINEAR LEAST SQUARES FIT
3640 PRINT CHR$(12)      ! CLEAR CRT
3650 ! INITIALIZE VARIABLES
3660 Sumx=0      ! SUM OF X VALUES
3670 Sumx2=0      ! SUM OF X SQUARED VALUES
3680 Sumy=0      ! SUM OF Y VALUES
3690 Sumy2=0      ! SUM OF Y SQUARED VALUES
3700 Sumxy=0      ! SUM OF THE PRODUCT
3710 FOR I=K1 TO K3      ! K1=INDEX OF FIRST, K3=INDEX OF LAST DATA POINT USED.
3720 !
3730 X=Codm(I)
3740 Y=Lodm(I)
3750 !
3760 Sumx=Sumx+X
3770 Sumy=Sumy+Y
3780 Sumx2=Sumx2+X*X
3790 Sumy2=Sumy2+Y*Y
3800 Sumxy=Sumxy+X*Y
3810 NEXT I
3820 K3=K3-P2      ! USED TO CALCULATE NUMBER OF DATA POINTS WITHIN BOUNDS.
3830 K4=K3-K1+1      ! K4-TOTAL # DATA POINTS USED IN CALC
3840 Qa1=Sumx2-Sumx*Sumx/K4
3850 Qa2=Sumxy-Sumx*Sumy/K4
3860 Qa3=Sumy2-Sumy*Sumy/K4
3870 !
3880 M=Qa2/Qa1      ! SLOPE
3890 !
3900 IF M<0 THEN 4190      ! IF SLOPE < 0, BAD DATA
3910 ! FROM DTNSRDC PROGRAM
3920 Q1=(K4*Sumx2-Sumx^2)/(K4*(K4-1))
3930 Q2=(K4*Sumy2-Sumy^2)/(K4*(K4-1))
3940 Q3=(K4-1)*(Q2-M*M*Q1)/(K4-2)
3950 Q4=SQR(Q3/(Q1*(K4-1)))
3960 !
3970 B=(Sumy-M*Sumx)/K4      ! INTERCEPT
3980 !
3990 Correl=M*SQR(Q1/Q2)
4000 !
4010 Qa4=SQR(ABS((Sumy2-B*Sumy-M*Sumxy)/(K4-2)))
4020 Signab=Qa4/SQR(ABS(Qa1))
4030 Signam=Signab*SQR(Sumx2/K4)
4040 Stiffm=M      ! STIFF = SLOPE
4050 Complm=1/M      ! COD COMPLIANCE = 1/SLOPE
4060 Compl=Complm*(4.448221615)/25.4      ! CONVERTS TO in/LB
4070 !
4080 ! STUDENT t TEST
4090 U4=Q4

```



```

4100 T9=1.96
4110 IF K4>120 THEN 4170 ! RETURNS
4120 T9=2.1
4130 IF K4<20 THEN 4170 ! RETURNS
4140 N9=K4-2
4150 T9=N9/(-.617109+N9*.510239)
4160 !
4170 RETURN
4180 !
4190 PRINT "POOR DATA-- SLOPE < 0"
4200 M=333333.3
4210 Correl=0
4220 !
4230 RETURN
4240 !
4250 !*****
4260 !
4270 Params: ! THIS ROUTINE WILL DETERMINE THE CURRENT MAX AND MIN LOAD FOR
FATIGUE PRECRACKING
4280 !
4290 ! NOTE THE USE OF ENGLISH UNITS DUE MTS READOUT BEING IN POUNDS.
4300 ! INITIALIZE VARIABLES
4310 Faw=0
4320 Pmax=0
4330 Pmin=0
4340 Delp=0
4350 Kmaxp=0
4360 Kminp=0
4370 Delk=0
4380 Delke=0
4390 !
4400 Opta=.6*W ! OPTIMUM CRACK LENGTH
4410 Dela=Opta-A1 ! EXTENSION REQUIRED
4420 Dela50=Dela*(.5)+A ! CRACK LENGTH AT 50% OF EXTENSION
4430 !
4440 Pmax=(4/3)*(Bmin*(W-A1)^2*Fs/(2*Hs)) ! FROM ASTM E813
4450 IF Flag3=1 THEN Pmax=(.4)*Pmax ! MAX LOAD DURING LAST 50% OF PRECR
ACKING (ASTM E813)
4460 Pmin=Pmax-.95*Pmax ! FROM ASTM E813
4470 Delp=Pmax-Pmin
4480 !
4490 ! DETERMINE Delk BASED ON P USING ASTM E399
4500 !
4510 Fawn=3*(A1/W)^.5*(1.99-(A1/W)*(1-A1/W)*(2.15-3.93*A1/W+2.7*(A1/W)^2))
4520 !
4530 Fawd=2*(1+2*A1/W)*(1-A1/W)^1.5
4540 !
4550 Faw=Fawn/Fawd
4560 !
4570 !
4580 Kmaxp=(Pmax*2*Hs/(Bmin*W^1.5))*Faw ! FROM ASTM E399
4590 Kminp=(Pmin*2*Hs/(Bmin*W^1.5))*Faw ! FROM ASTM E399
4600 Delk=Kmaxp-Kminp
4610 !
4620 ! DETERMINE Delke BASED ON MODULUS FROM ASTM E813
4630 IF Flag3=0 THEN Delke=40000 ! DURING EARLY EXTENSION
4640 IF Flag3=1 THEN Delke=(.001)*E ! DURING LAST 50% OF PRECRACKING (RE
F. ASTM E399 & E813)
4650 PRINT ""

```



```

4660 PRINT "BASED ON CURRENT INFORMATION:"
4670 PRINT ""
4680 PRINT "CURRENT CRACK LENGTH =";A1;"in"
4690 PRINT "OPTIMUM a0="";Opta:"in"
4700 PRINT "EXTENSION REQUIRED =";Dela
4710 PRINT "CRACK LENGTH AT 50% OF EXTENSION =";Dela50;"in"
4720 PRINT "Pmax =";Pmax;"Lbs Pmin =";Pmin;"Lbs"
4730 PRINT "Kmaxp =";Kmaxp;" Kminp =";Kminp
4740 PRINT "DELTA_K =";Delk;"in^.5"
4750 PRINT "DELTA_KE =";Delke;"in^.5"
4760 PRINT "FAW =";Faw ! SERVES AS A CHECK
4770 PRINT ""
4780 PRINT "IF Delk > Delke. Pmax MUST BE DECREASED"
4790 IF Delk<Delke THEN 4900 ! SKIP IF OKAY
4800 ! COMPUTE NEW Pmax
4810 Delpl=(Delke/Faw/(2*Hs)*Bmin*W^1.5)
4820 Pmax1=Delpl/.95
4830 Pmin1=Pmax1-.95*Pmax1
4840 Kmax1=(Pmax1*2*Hs/(Bmin*W^1.5))*Faw
4850 PRINT "THE NEW Pmax BASED ON Delke IS:";Pmax1;"Lbs"
4860 PRINT "NEW Pmin =";Pmin1;"Lbs"
4870 PRINT "NEW DELTA_P =";Delpl;"Lbs"
4880 PRINT "NEW Kmax =";Kmax1
4890 !
4900 PRINT " DO YOU WANT A HARD COPY?"
4910 INPUT HS
4920 IF HS="N" OR HS="NO" THEN 5080
4930 PRINTER IS 706 ! TOGGLES PRINTER
4940 PRINT "BASED ON CURRENT INFORMATION FOR ";Ds;":"
4950 PRINT ""
4960 PRINT "CURRENT CRACK LENGTH =";A1;"in"
4970 PRINT "OPTIMUM CRACK LENGTH =";Opta;"in"
4980 PRINT "EXTENSION REQUIRED =";Dela;"in"
4990 PRINT "CRACK LENGTH AT 50% OF EXTENSION =";Dela50;"in"
5000 PRINT "Pmax =";Pmax;"Lbs Pmin =";Pmin;"Lbs"
5010 PRINT "Delp =";Delp;"Lbs Kmax =";Kmaxp
5020 PRINT "DELTA_K =";Delk;"in^.5 DELTA_KE =";Delke;"in^.5"
5030 IF Delk<Delke THEN 5090
5040 PRINT ""
5050 PRINT "NEW LOADS BASED ON DELTA_KE ARE:"
5060 PRINT "Pmax =";Pmax1;"Lbs Pmin =";Pmin1;"Lbs"
5070 PRINT "DELTA_P =";Delpl;"Lbs Kmax =";Kmax1
5080 PRINT ""
5090 PRINTER IS 1 ! TOGGLES PRINTER TO CRT
5100 PRINT ""
5110 PRINT "MAKE THE NECESSARY ADJUSTMENTS BEFORE CONTINUING."
5120 PRINT "WHEN COMPLETED PRESS 'CONTINUE'."
5130 INPUT CS
5140 !
5150 RETURN
5160 !
5170 !*****
5180 !
5190 A table: ! PRODUCES TABULATED VALUES FOR LOAD vs COD VALUES AT VARIOU
S CRACK LENGTHS
5200 !
5210 PRINT "BEFORE YOU CAN RUN THIS SUBROUTINE YOU MUST ENTER:"
5220 PRINT " 1. SPECIMEN DATA"
5230 PRINT " 2. CONVERSION DATA"

```



```

5240 PRINT ""
5250 PRINT "ARE YOU READY?"
5260 INPUT HS
5270 IF HS="N" OR HS="NO" THEN 5550 ! RETURNS TO k-KEY SELCETION
5280 !
5290 Beff=Bmax-(Bmax-Bmin)^2/Bmax ! IAW ASTM E813-81
5300 PRINT "BEFF =";Beff
5310 !
5320 ! USING CRACK LENGTH EQUATION FROM DTNSRDC PROGRAM CALC CRACK LENGTH FOR
VARIOUS VALUES OF U
5330 A00=.998265
5340 A1=-3.81662
5350 A2=-1.80596
5360 A3=32.31038
5370 A4=-44.15665
5380 A5=-52.67876
5390 FOR U=.07 TO .155 STEP .005
5400 Ar=A00+A1*U+A2*U^2+A3*U^3+A4*U^4+A5*U^5
5410 Ck1=Ar*W
5420 PRINTER IS 706 ! TOGGLES TO THERMAL PRINTER
5430 PRINT "U =";U
5440 PRINT "a/W =";Ar;"in CRACK LENGTH =";Ck1;"in"
5450 PRINT "LOAD (lbs) COD (in) COD (Volts)"
5460 FOR Lod1=200 TO 1800 STEP 100
5470 C=Beff*W*E^2/Hs
5480 Cod1=Lod1*((1-U)/U)^2/C
5490 Codv=Cod1/S1(2)
5500 PRINT Lod1,Cod1,Codv
5510 NEXT Lod1
5520 NEXT U
5530 PRINTER IS 1 ! RETURNS TO USING CRT AS PRINTER
5540 !
5550 RETURN
5560 !
5570 !*****
5580 !
5590 End_precrack: ! END OF PRECRACKING
5600 !
5610 PRINT " PRECRACKING IS COMPLETED!"
5620 PRINT ""
5630 PRINT "FINAL CRACK LENGTH =";A0(D2-1)
5640 PRINT "CORRELATION OF DATA =";Correl
5650 PRINT ""
5660 PRINT " REMOVE SPECIMEN FROM MTS."
5670 !
5680 END

```


APPENDIX E

J_INTGL LISTING

```
10 ! J-INTEGRAL FRACTURE TOUGHNESS PROGRAM
20 ! FOR THREE POINT BEND SPECIMEN. THIS
30 ! PROGRAM INCORPORATES THE USE OF THE
40 ! FOLLOWING EQUIPMENT:
50 !     1. HP-9826 COMPUTER
60 !     2. HP-3497A DATA ACQUISITION SYSTEM
70 !     3. HP-3437A SYSTEM VOLTMETER
80 !     4. HP-2671G THERMAL PRINTER
90 !     5. HP-7225B PLOTTER
100 !
110 ! THIS PROGRAM WAS WRITTEN BY:
120 !     LCDR W. K. TRITCHLER, USN
130 ! VERSION 1.0     DATE 11/83
140 !
150 !
160 !
170 COM /J_intgl/ F1
180 !
190 ! DIM Lod(8000).Defl(8000).Cod(8000)
200 ! NOTE: Lod, Defl AND Cod ARE ACTUALLY DIMENSIONED IN Initial_a ROUTINE
210 ! Lod(I) = LOAD
220 ! Defl(I) = DEFLECTION
230 ! Cod(I) = CRACK OPENING DISPLACEMENT (COD)
240 !
250 DIM A0(50).Amin0(50).Amax0(50).Comp10(50).Correl0(50)
260 DIM Area9(100).A1(100).Coef(6).G(6)
270 DIM J9(100).Delta_a(100).Mdefl(100)
280 DIM Data5(1:4)(10)
290 DUMP DEVICE IS 706 ! THERMAL PRINTER ADDRESS
300 Dvm=709 ! DATA ACQUISITION ADDRESS
310 CLEAR Dvm
320 PRINT CHR$(12) ! CLEARS CRT
330 PRINT ""
340 PRINT " J-INTEGRAL TEST PROGRAM"
350 PRINT " VERSION 1.0"
360 PRINT " WRITTEN BY LCDR W.K. TRITCHLER"
370 PRINT ""
380 PRINT " PLEASE SELECT A k-KEY"
390 !
400 ! *****
410 Begin: !
420 ON KEY 0 LABEL "SPEC_DATA" GOSUB Spec_data
430 ON KEY 1 LABEL "CONV_DATA" GOSUB Conv_data
440 ON KEY 2 LABEL "DAT_FILE" GOSUB Data_file
450 ON KEY 3 LABEL "PLOTTER" GOSUB Setup_plotter
460 ON KEY 4 LABEL "GCLEAR" GOSUB Gclr
470 ON KEY 5 LABEL "a0" GOSUB Initial_a
480 ON KEY 7 LABEL "START" GOSUB Main_prog
490 ! (*) ON KEY 8 LABEL "R-CURVE" GOSUB R_curve
500 ! (SEE NOTES ON (*) IN R_curve ROUTINE
510 ON KEY 9,4 CALL Stop_test
520 !
530 ! *****
540 !
550 Spin: ! WAITS FOR KEY INPUT
560 GOTO Spin
570 !
580 ! *****
590 !
```



```

600 Gclr:      ! GRAPHICS SCREEN CLEAR
610 ! THIS ROUTINE ALLOWS SINGLE KEY STROKE TO REMOVE A GRAPHICS DISPLAY FROM
CRT
620 GCLEAR
630 RETURN ! RETURNS TO k-KEY SELECTION
640 !
650 !-----
660 !
670 Spec_data: ! INPUTS REQUIRED SPECIMEN DATA
680 PRINT CHR$(12) ! CLEARS CRT
690 PRINT "INPUT SPECIMEN IDENTIFICATION (ID):"
700 INPUT Ds
710 PRINT ""
720 PRINT "J-INTEGRAL TEST for ";Ds
730 PRINT ""
740 PRINT "INPUT SPECIMEN DATA USING ENGLISH UNITS (LBS.      INCHES, etc.)"
750 PRINT ""
760 PRINT "WHAT IS THE SPECIMEN'S WIDTH, NOTCH LENGTH, Bmax, Bmin (THICKNESS)
?"
770 INPUT W,A,Bmax,Bmin
780 PRINT ""
790 PRINT "WHAT IS THE SPECIMEN'S HALF SPAN AND POISSON'S      RATIO?"
800 INPUT Hs,Nu
810 PRINT ""
820 PRINT "WHAT IS THE SPECIMEN'S ELASTIC MODULUS, YIELD      STRENGTH AND ULT
IMATE STRENGTH?"
830 INPUT E,Ys,Uts
840 PRINT CHR$(12) ! CLEARS CRT
850 Fs=(Ys+Uts)/2
860 PRINT "USING ENGLISH UNITS (in,lbs,psi)"
870 PRINT "THE FOLLOWING HAS BEEN ENTERED for: ";Ds
880 PRINT "WIDTH =";W;"      NOTCH LENGTH =";A
890 PRINT "Bmax =";Bmax;"      Bmin =";Bmin
900 PRINT "HALF SPAN =";Hs;"      POISSON'S RATIO =";Nu
910 PRINT "YIELD STRENGTH =";Ys;"      ULTIMATE TS =";Uts
920 PRINT "ELASTIC MODULUS =";E;"      FLOW STRESS =";Fs
930 PRINT ""
940 PRINT "THIS PROGRAM ALLOWS NO EASY RECOVERY, IF ANY DATA IS INCORRECT YOU
MUST RE-ENTER ";
950 PRINT "EVERYTHING."
960 PRINT ""
970 PRINT "IS ALL DATA CORRECT?"
980 INPUT Hs
990 IF Hs="NO" OR Hs="N" THEN 670 ! REPEATS Spec_data
1000 PRINT ""
1010 PRINT "DO YOU WANT A HARD COPY?"
1020 INPUT Hs
1030 IF Hs="N" OR Hs="N" THEN 1180
1040 !
1050 PRINTER IS 706 ! TOGGLES PRINTER TO THERMAL PRINTER
1060 PRINT ""
1070 PRINT "USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION"
1080 PRINT "HAS BEEN ENTERED FOR: ";Ds
1090 PRINT ""
1100 PRINT "WIDTH =";W;"      NOTCH LENGTH =";A
1110 PRINT "Bmax =";Bmax;"      Bmin =";Bmin
1120 PRINT "HALF SPAN =";Hs;"      POISSON'S RATIO =";Nu
1130 PRINT "YIELD STRENGTH =";Ys;"      ULTIMATE TS =";Uts
1140 PRINT "ELASTIC MODULUS =";E;"      FLOW STRESS =";Fs
1150 PRINT ""

```



```

1160 PRINTER IS 1          ! TOGGLES PRINTER BACK TO CRT
1170 !
1180 PRINT CHR$(12)        ! CLEARS CRT
1190 !
1200 ! CONVERSION TO METRIC UNITS
1210 Conlen=25.4           ! 1in = 25.40mm
1220 W=W*Conlen
1230 A=A*Conlen
1240 Bmax=Bmax*Conlen
1250 Bmin=Bmin*Conlen
1260 Hs=Hs*Conlen
1270 Conpress=6.89475293   ! 1psi = 6.89475293kPa (HP PROGRAMING BOOK)
1280 E=E*Conpress
1290 Ys=Ys*Conpress
1300 Uts=Uts*Conpress
1310 Fs=Fs*Conpress
1320 !
1330 PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa)      for ";Ds;" YIEL
DS:"
1340 PRINT "WIDTH =";W;"    NOTCH LENGTH =";A
1350 PRINT "Bmax =";Bmax;"    Bmin =";Bmin
1360 PRINT "HALF SPAN =";Hs;"    POISSON'S RATIO =";Nu
1370 PRINT "YIELD STRENGTH =";Ys;"    UTILMATE TS =";Uts
1380 PRINT "ELASTIC MODULUS =";E;"    FLOW STRESS =";Fs
1390 PRINT ""
1400 PRINT "DO YOU WISH TO HAVE A PRINT OUT OF THIS DATA?"
1410 INPUT G$
1420 IF G$="N" OR G$="NO" THEN 1540
1430 !
1440 PRINTER IS 706          ! TOGGLES TO THERMAL PRINTER
1450 PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: ";Ds
1460 PRINT "WIDTH =";W;"    NOTCH LENGTH =";A
1470 PRINT "Bmax =";Bmax;"    Bmin =";Bmin
1480 PRINT "HALF SPAN =";Hs;"    POISSON'S RATIO =";Nu
1490 PRINT "YIELD STRENGTH =";Ys;"    ULTIMATE TS =";Uts
1500 PRINT "ELASTIC MODULUS =";E;"    FLOW STRESS =";Fs
1510 PRINT ""
1520 PRINTER IS 1          ! TOGGLES PRINTER TO CRT
1530 !
1540 PRINT CHR$(12)        ! CLEAR CRT
1550 !
1560 RETURN                ! RETURNS TO k-KEY SELECTION
1570 !
1580 !*****
1590 !
1600 Setup_plotter: ! SET UP INTERACTIVE PLOTTER
1610 ! YOU CAN CHOOSE BETWEEN THREE DIFFERENT PLOTS
1620 ! (P vs COD, P vs DEFLECTION, OR J vs DELTA_A)
1630 PRINT CHR$(12)        ! CLEARS CRT
1640 DIM TS(80),XS(80),YS(80)
1650 GCLEAR
1660 GINIT
1670 GRAPHICS ON
1680 PLOTTER IS 3,"INTERNAL"    ! PLOTS ON CRT FOR VIEWING BEFORE SENDING TO
HP-7225B PLOTTER
1690 PRINT "TYPE OF PLOT:"
1700 PRINT "    1. LOAD vs COD"
1710 PRINT "    2. LOAD vs DEFLECTION"
1720 PRINT "    3. J vs CRACK EXTENSION"
1730 PRINT "ENTER THE # OF THE PLOT YOU DESIRE"

```



```

1740 INPUT C2
1750 PRINT ""
1760 PRINT ""
1770 IF C2=1 THEN 1810
1780 IF C2=2 THEN 1860
1790 IF C2=3 THEN 1910
1800 PRINT ""
1810 TS="PLOT of LOAD vs COD for "&D$
1820 PRINT TS
1830 XS="COD (mm)"
1840 YS="LOAD (N)"
1850 GOTO 1950
1860 TS="PLOT of LOAD vs DEFLECTION for "&D$
1870 PRINT TS
1880 XS="DEFLECTION (mm)"
1890 YS="LOAD (N)"
1900 GOTO 1950
1910 TS="PLOT of J vs CRACK EXTENSION for "&D$
1920 PRINT TS
1930 XS="DELTA_a (mm)"
1940 YS="J (kJ/m^2)"
1950 PRINT ""
1960 PRINT "USING METRIC UNITS (mm,N,kJ/m^2,etc):"
1970 PRINT "ENTER HERE THE Xmin,Xmax,Ymin,Ymax"
1980 INPUT X1(C2),X2(C2),Y1(C2),Y2(C2)
1990 X3=X2(C2)-X1(C2)
2000 Y3=Y2(C2)-Y1(C2)
2010 VIEWPORT 13,100*RATIO,10,90
2020 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2030 PRINT ""
2040 PRINT "INPUT DELTA_X AND DELTA_Y LABEL INTERVAL"
2050 PRINT "FOR THE TWO AXES:"
2060 INPUT X4,Y4
2070 PRINT ""
2080 PRINT "DO YOU WISH TO HAVE A GRID OVERLAY?"
2090 INPUT G$
2100 IF G$="NO" OR G$="N" THEN 2140
2110 PRINT ""
2120 PRINT "INPUT GRID LINES PER DELTA LABEL:"
2130 INPUT B0
2140 PRINT "PRESS 'ENTER' TO PLOT"
2150 INPUT H$
2160 PRINT CHR$(12) ! CLEARS CRT <-----
2170 IF G$="NO" OR G$="N" THEN 2310
2180 FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
2190 MOVE I,Y1(C2)
2200 DRAW I,Y2(C2)
2210 NEXT I
2220 FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
2230 MOVE X1(C2),I
2240 DRAW X2(C2),I
2250 NEXT I
2260 GOTO 2320
2270 IF G$="Y" OR G$="YES" THEN 2320
2280 MOVE X2(C2),Y1(C2)
2290 DRAW X2(C2),Y2(C2)
2300 DRAW X1(C2),Y2(C2)
2310 CLIP ON
2320 AXES X4,Y4,X1(C2),Y1(C2)
2330 CLIP OFF

```



```

2340 VIEWPORT 13.100*RATIO,5.90
2350 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2360 LORG 4
2370 CSIZE 3..6          ! LABELS X DIGITS
2380 FOR X=X1(C2) TO X2(C2) STEP X4
2390     CLIP OFF
2400     MOVE X,Y1(C2)
2410     CLIP OFF
2420     LABEL USING "K";X
2430 NEXT X
2440 VIEWPORT 4.100*RATIO,10.90
2450 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2460 LORG 2              ! LABELS Y DIGITS
2470 FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2480     CLIP OFF
2490     MOVE X1(C2),Y
2500     CLIP OFF
2510     LABEL USING "K";Y
2520 NEXT Y
2530 VIEWPORT 0,RATIO=100,0,100
2540 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2550 CSIZE 5
2560 LORG 6              ! PLOTS TITLE
2570     MOVE X2(C2)/2,Y2(C2)
2580     LABEL T$
2590 DEG
2600 LDIR 90
2610 CSIZE 4..7
2620     MOVE X1(C2),Y2(C2)/2
2630     LABEL Y$          ! PLOTS Y-AXIS LABEL
2640 LORG 4
2650 LDIR 0
2660     MOVE X2(C2)/2,Y1(C2)
2670     LABEL X$          ! PLOTS X-AXIS LABEL
2680 !
2690 PRINT ""
2700 PRINT ""
2710 PRINT ""
2720 PRINT ""
2730 PRINT "          IS THE PLOT (AXES AND LABELS) OK?"
2740 PRINT ""
2750 PRINT "          NOTE:  IF YOU ANSWER YES OR Y"
2760 PRINT "          PLOT WILL BE PRODUCED"
2770 PRINT "          ON EXTERNAL PLOTTER."
2780 INPUT F$
2790 IF F$="N" OR F$="NO" THEN GOSUB Setup_plotter  ! REDO PLOTTER SETUP
2800 !
2810 GCLEAR              ! CLEARS PLOT FROM CRT
2820 !
2830 GOSUB Ext_plotter   ! SENDS PLOT TO PLOTTER
2840 !
2850 PENUP
2860 MOVE 0,0
2870 !
2880 RETURN              ! RETURNS TO k-KEY SELECTION OR R_curve ROUTINE
2890 !
2900 !*****
2910 !
2920 Ext_plotter:  ! DUMPS PLOTTER SETUP TO EXTERNAL HP-7225B PLOTTER
2930 !

```



```

2940 PLOTTER IS 705,"HPGL"
2950 VIEWPORT 13,100=RATIO,10,90
2960 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2970 IF G5="NO" OR G5="N" THEN 3080
2980 FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
2990     MOVE I,Y1(C2)
3000     DRAW I,Y2(C2)
3010 NEXT I
3020 FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
3030     MOVE X1(C2),I
3040     DRAW X2(C2),I
3050 NEXT I
3060 GOTO 3120
3070 IF G5="Y" OR G5="YES" THEN 3120
3080 MOVE X2(C2),Y1(C2)
3090 DRAW X2(C2),Y2(C2)
3100 DRAW X1(C2),Y2(C2)
3110 CLIP ON
3120 AXES X4,Y4,X1(C2),Y1(C2)
3130 CLIP OFF
3140 VIEWPORT 13,100=RATIO,5,90
3150 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3160 LG 4
3170 CSIZE 3,.6          ! SIZE OF DIGITS
3180 FOR X=X1(C2) TO X2(C2) STEP X4
3190     CLIP OFF
3200     MOVE X,Y1(C2)
3210     CLIP OFF
3220     LABEL USING "K";X      ! LABELS X-AXIS
3230 NEXT X
3240 VIEWPORT 4,100=RATIO,10,90
3250 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3260 LG 2
3270 FOR Y=Y1(C2) TO Y2(C2) STEP Y4
3280     CLIP OFF
3290     MOVE X1(C2),Y
3300     CLIP OFF
3310     LABEL USING "K";Y      ! LABELS Y-AXIS
3320 NEXT Y
3330 VIEWPORT 0,100=RATIO,0,100
3340 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3350 CSIZE 5              ! TITLE SIZE
3360 LG 6
3370     MOVE X2(C2)/2,Y2(C2)
3380     LABEL T5              ! PRINTS TITLE
3390 DEG
3400 LDIR 90
3410 CSIZE 4,.7
3420     MOVE X1(C2),Y2(C2)/2
3430     LABEL Y5              ! PRINTS Y-AXIS TITLE
3440 LG 4
3450 LDIR 0
3460     MOVE X2(C2)/2,Y1(C2)
3470     LABEL X5              ! PRINTS X-AXIS TITLE
3480 PENUP
3490 MOVE 0,0
3500 !
3510 RETURN'              ! RETURNS TO Setup_plotter
3520 !
3530 !*****

```



```

3540 !
3550 Initial_a: ! ESTIMATES INITIAL CRACK LENGTH
3560 Beff=Bmax-(Bmax-Bmin) 2/Bmax ! USES B(EFFECTIVE) FROM ASTM E813-81
3570 D2=1 ! INITIALIZES COUNTER
3580 PRINT CHR$(12) ! CLEARS CRT
3590 PRINT "BEFORE YOU CAN RUN THIS ROUTINE YOU MUST:"
3600 PRINT " 1. ENTER SPECIMEN DATA"
3610 PRINT " 2. ENTER CONVERSION DATA"
3620 PRINT " 3. SET UP PLOTTER"
3630 PRINT " 4. CREATE DATA FILE"
3640 PRINT ""
3650 PRINT "ARE YOU READY?"
3660 INPUT HS
3670 IF HS="N" OR HS="NO" THEN 5070 ! RETURNS TO KEY SELECTION SCREEN
3680 PRINT CHR$(12) ! CLEARS CRT
3690 PRINT "THIS ROUTINE WILL OBTAIN THE INITIAL CRACK LENGTH AFTER FATIGUE PRE
-CRACKING."
3700 PRINT ""
3710 PRINT "YOU MAY LOAD AND UNLOAD THE SPECIMEN AS OFTEN AS YOU LIKE -- BUT Y
OU MUST REMAIN ";
3720 PRINT "ON THE LINEAR PORTION OF THE CURVE!"
3730 PRINT ""
3740 PRINT "NOTE: THE MTS SHOULD BE IN 'STROKE' CONTROL"
3750 PRINT " AT A VERY SLOW INVERTED RAMP FUNCTION"
3760 PRINT " RATE OR YOU MAY DO THIS WITH MANUAL LOAD"
3770 PRINT " CONTROL."
3780 PRINT ""
3790 !
3800 PRINT "WOULD YOU LIKE AN ESTIMATE OF Pmax (Lbs)?"
3810 INPUT ES
3820 IF ES="N" OR ES="NO" THEN 4060 ! SKIPS Pmax CALC
3830 !
3840 PRINT "YOU MUST PROVIDE AN ESTIMATE OF CURRENT CRACK LENGTH"
3850 PRINT "INPUT YOUR ESTIMATE IN INCHES."
3860 INPUT Aest
3870 ! CONVERT ALL DIMENSIONS BACK TO ENGLISH UNITS.
3880 ! a0 IS SUFFIX ON ALL VARIABLES FOR THIS CALC.
3890 Beffa0=Beff/Conlen
3900 Wa0=W/Conlen
3910 Blig=(Wa0-Aest) ! ESTIMATED LENGTH OF UNBROKEN LIGAMENT IN INCHES
3920 Fsa0=Fs/Conpress
3930 Hsa0=Hs/Conlen
3940 Pla0=.533*Beffa0*Blig^2*Fsa0/(2*Hsa0)
3950 PRINT "AN ESTIMATE OF Pmax IS";Pla0
3960 PRINT "Pmax ESTIMATES THE POINT AT WHICH THE CURVE"
3970 PRINT "BECOMES NONLINEAR, IAW ASTM E813-81"
3980 !
3990 PRINTER IS 706 ! TOGGLES PRINTER
4000 PRINT ""
4010 PRINT "GIVEN a=";Aest;"inches THEN:"
4020 PRINT " Pmax=";Pla0;"Lbs FROM ASTM E813-81"
4030 PRINT ""
4040 PRINTER IS 1
4050 !
4060 DIM Lod(8000),Defl(8000),Cod(8000)
4070 !
4080 ! ASSIGN DEFL CORRECTION COEF USED IN Data_acq AND Take_data ROUTINES
4090 ! THIS USES A 4th ORDER POLYNOMIAL FIT OF RECORDED DATA ON THE MTS SYSTEM
S COMPLIANCE
4100 !

```



```

4110 Corr(1)=5.798E-5
4120 Corr(2)=4.7419E-6
4130 Corr(3)=-2.803E-9
4140 Corr(4)=1.471E-12
4150 Corr(5)=-2.7741E-16
4160 !
4170 PRINT ""
4180 PRINT "WHEN YOU ARE READY TO BEGIN PRESS THE 'ENTER' KEY."
4190 INPUT HS
4200 PRINT CHR$(12) ! CLEARS CRT
4210 K=0 ! USED AS A COUNTER
4220 I=1 ! USED AS INDEX
4230 Flag1=0 ! NOTE: FLAG1 AND FLAG2 ARE RESET
4240 Flag2=0 ! IN Data_acq ROUTINE
4250 WHILE Flag1=0 ! ESTABLISHES ONE LOAD-UNLOAD DATA TAKING LOOP
4260 GOSUB Data_acq
4270 END WHILE
4280 Flag2=0 ! RESETS FLAG2
4290 WHILE Flag2=0
4300 GOSUB Data_acq
4310 END WHILE
4320 PENUP
4330 ! THIS SECTION CAN BE USED TO VIEW THE COLLECTED DATA BY REMOVING THE REM
ARK CHARACTER (!).
4340 ! FOR I=1 TO K
4350 ! PRINT USING 3780;I,Lod(I),Defl(I),Cod(I)
4360 ! IMAGE X,3D,4X,6D,0,4X,3D,7D,7X,3D,7D
4370 ! NEXT I
4380 ! WAIT 5
4390 K1=1
4400 K3=K
4410 GOSUB Slope ! SLOPE = 1/COD COMPLIANCE
4420 Correl0(D2)=Correl ! SAVES CURRENT CORRELATION COEFFICIENT IN AN ARRAY
4430 !
4440 Compl0(D2)=Compl ! SAVES CURRENT COMPLINACE VALUE IN AN ARRAY
4450 !
4460 GOSUB Crack_length ! USES COD COMPLIANCE
4470 !
4480 A0(D2)=Crck1 ! SAVE THE LAST a0 MEASUREMENT OBTAINED IN AN ARRAY
4490 !
4500 ! FIND 95% CONFIDENCE INTERVAL FOR a0
4510 Stiff=Stiff+T9*U4
4520 GOSUB Crack_length
4530 Amax0(D2)=Crck1
4540 Stiff=Stiff-2*T9*U4
4550 GOSUB Crack_length
4560 Amin0(D2)=Crck1
4570 !
4580 !
4590 PRINT CHR$(12) ! CLEARS CRT
4600 PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
4610 PRINT ""
4620 PRINT "INITIAL CRACK LENGTH (a0) =";A0(D2);"mm FROM MEASUREME
NT #";D2
4630 PRINT ""
4640 PRINT "WITH 95% CONDIFENCE INTERVAL ON a FROM";Amin0(D2);" TO";Amax0(D2);"
mm"
4650 PRINT ""
4660 PRINT "USING COD COMPLIANCE OF";Compl0(D2);"mm/N"
4670 PRINT "WITH A CORRELATION OF";Correl0(D2);"FROM";K;"DATA POINTS."

```



```

4580 PRINT ""
4690 PRINT "DO YOU WANT A HARD COPY?"
4700 INPUT HS
4710 IF HS="N" OR HS="NO" THEN 4830
4720 !
4730 PRINTER IS 706 ! TOGGLES PRINTER
4740 PRINT ""
4750 PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
4760 PRINT "INITIAL CRACK LENGTH =":A0(D2):"mm FROM MEASUREMENT #":D2
4770 PRINT "WITH 95% CONFIDENCE INTERVAL FROM":Amin0(D2):" TO":Amax0(D2):"mm"
4780 PRINT "USING COD COMPLIANCE OF":Comp10(D2):"mm/N"
4790 PRINT "WITH A CORRELATION OF":Correl0(D2):"FROM":K:"DATA POINTS."
4800 PRINT ""
4810 PRINTER IS 1 ! TOGGLES PRINTER
4820 !
4830 D2=D2+1 ! INCREMENT COUNTER
4840 PRINT ""
4850 PRINT "DO YOU WANT ANOTHER a0 MEASUREMENT?"
4860 INPUT G3
4870 IF G3="Y" OR G3="YES" THEN 4060
4880 !
4890 PRINT "INPUT THE NUMBER (#) OF THE a0 MEASUREMENT YOU WISH TO USE AND S
TORE."
4900 PRINT " NOTE: ONLY THIS SET OF DATA ARE"
4910 PRINT " STORED ON DISK."
4920 INPUT D2
4930 !
4940 A1=A0(D2) ! ASSIGNS A1 TO DESIRED A0(D2) VALUE
4950 ! NOTE: A1 IS USED IN Main_prog AS INITIAL CRACK LENGTH VALUE
4960 !
4970 PRINT ""
4980 PRINT "YOU HAVE SELECTED MEASUREMENT #":D2
4990 PRINT " ARE YOU SURE?"
5000 INPUT P5
5010 ! NOTE: ONLY THIS a0 MEASUREMENT IS STORED ON DISK
5020 !
5030 IF P5="N" OR P5="NO" THEN 4890 ! ALLOWS CORRECTION
5040 K2=0 ! K2 IS UNLOADING COUNTER THIS WILL ENSURE CORRECT DAT
A IS STORED
5050 GOSUB Stor_data ! <-----** WRITES ON DISK
5060 !
5070 PRINT CHR$(12)
5080 !
5090 !
5100 RETURN ! RETURNS TO k-KEY SELECTION
5110 !
5120 !*****
5130 !
5140 Data_acq: ! DATA ACQUISITION ROUTINE
5150 OUTPUT Dvm;"VRS AF1 AL3"
5160 !
5170 OUTPUT Dvm;"AI1 VT1" ! READS LOAD
5180 ENTER Dvm:Lod(I)
5190 Lod(I)=Lod(I)*S1(1)
5200 !
5210 OUTPUT Dvm;"AI2 VT1" ! READS COD
5220 ENTER Dvm:Cod(I)
5230 Cod(I)=(Cod(I))*S1(2)
5240 ! NOTE: COD IS CALIBRATED ONLY FORM 0.475 TO 0.625 INCHES (MAX COD IS 0.1
5 INCHES)

```



```

5250 !
5260 OUTPUT Dvm:"AI3 VT1" ! READS DEFLECTION
5270 ENTER Dvm:Defl(I)
5280 Defl(I)=Defl(I)*S1(3)
5290 !
5300 GOSUB Correct_defl ! DETERMINE DEFL CORRECTION FACTOR
5310 !
5320 Defl(I)=Defl(I)-Totcor
5330 !
5340 !
5350 ! PLOT THE DATA POINT
5360 VIEWPORT 13,100*RATIO,10,90
5370 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
5380 IF C2=2 THEN 5410
5390 PLOT Cod(I),Lod(I)
5400 GOTO 5420
5410 PLOT Defl(I),Lod(I)
5420 !
5430 ! TAKE DATA FOR ONE COMPLETE LOADING AND UNLOADING
5440 IF I=1 THEN 5520 ! SKIPS TEST ON THE FIRST DATA POINT
5450 !
5460 ! TEST DATA
5470 Lodiff=Lod(I)-Lod(I-1)
5480 IF Lodiff<-25.0 THEN Flag1=1 ! MUST BE UNLOADING
5490 IF Lodiff>25.0 THEN Flag2=1 ! MUST BE LOADING
5500 Lodiff=0.
5510 !
5520 I=I+1 ! INCREMENTS INDEX
5530 !
5540 K=K+1 ! INCREMENT COUNTER
5550 !
5560 RETURN ! RETURNS TO Initial_a ROUTINE
5570 !
5580 !*****
5590 Correct_defl: ! THIS ROUTINE CALCULATES THE DEFLECTION CORRECTION FACT
OR
5600 !
5610 ! CORRECTION FACTOR IS REQUIRED TO ACCOUNT FOR SYSTEM COMPLIANCE
5620 ! A 4TH ORDER POLYNOMIAL FIT WAS PREVIOUSLY DETERMINED.
5630 !
5640 ! NOTE: *****
5650 ! THE 5 CORRECTION COEFFICIENTS CORR(I) WERE ASSIGNED IN Initial_a ROUTIN
E TO SPEED UP PROG.
5660 ! *****
5670 !
5680 Lodp=Lod(I)/Conlb ! CONVERTS CURRENT LOAD TO Lbs FOR CALC
5690 Deflc(1)=Lodp
5700 FOR J=2 TO 4
5710 Deflc(J)=Deflc(J-1)*Deflc(1)
5720 NEXT J
5730 Totcor=Corr(1) ! PREVIOUSLY ASSIGNED AS NOTED.
5740 FOR J=1 TO 4
5750 Totcor=Totcor+Corr(J+1)*Deflc(J)
5760 NEXT J
5770 !
5780 Totcor=Totcor*Conlen ! CONVERTS TOTAL CORRECTION FACTOR FROM (in) TO (
mm)
5790 !
5800 !
5810 RETURN ! RETURNS TO Data_acq OR Take_data ROUTINE

```



```

5820 !
5830 !-----
5840 !
5850 Crack length: ! CALCULATES CRACK LENGTH USING HUDAK (DTNSRDC PROG) [PROF. J
. JOYCE'S EQUATION]
5860 ! NOTE: THIS ROUTINE USES COD COMPLIANCE METHOD VICE DEFLECTION COMPLIA
NCE.
5870 FOR I=1 TO 5
5880 READ Coef(I)
5890 NEXT I
5900 Compl=1/Stiff
5910 C=2*W*Beff*E*Compl/Hs/1000
5920 C=1/(SQR(C)+1)
5930 G(1)=C
5940 FOR I=2 TO 5
5950 G(I)=G(I-1)*G(1)
5960 NEXT I
5970 F=Coef(1)
5980 FOR I=1 TO 5
5990 F=F+Coef(I+1)*G(I)
6000 NEXT I
6010 Crckl=F*W
6020 RESTORE
6030 DATA 0.998265,-3.81662,-1.80596,32.31038,-44.15665,-52.67876
6040 !
6050 RETURN ! RETURNS TO Initial_a OR Main_prog
6060 !
6070 !-----
6080 !
6090 Conv_data: ! INPUTS CONVERSION DATA FOR MEASURING DEVICES
6100 PRINT CHR$(12) ! CLEARS CRT
6110 PRINT "INPUT: LOAD RANGE, STRAIN RANGE, STROKE RANGE"
6120 PRINT " (ENTER IN PERCENT ie. 10,20,50,100)"
6130 INPUT Lr,Cr,Sr
6140 PRINT ""
6150 PRINT "LOAD RANGE = ";Lr
6160 PRINT "STRAIN (COD) RANGE = ";Cr
6170 PRINT "STROKE (DEFLECTION) RANGE = ";Sr
6180 Lmax=20000 ! MAX LOAD RANGE IN (lbs).
6190 Cmax=.200 ! MAX COD RANGE IN (in).
6200 Smax=5.0 ! MAX STROKE RANGE IN (in).
6210 V=10 ! MAX VOLTAGE IN (volts).
6220 !
6230 ! MAXIMUM OPERATING POINTS ARE:
6240 Olmax=Lmax*Lr/100
6250 Ocmax=Cmax*Cr/100
6260 Osmax=Smax*Sr/100
6270 !
6280 ! CONVERSION CONSTANTS ARE: (ENGLISH UNITS)
6290 Sle(1)=Olmax/V
6300 Sle(2)=Ocmax/V
6310 Sle(3)=Osmax/V
6320 ! CONVERTING TO METRIC:
6330 Conlen=25.4 ! 25.4mm = 1in
6340 Conlb=4.448221615 ! 4.448221615N = 1lb (HP PROGRAMING BOOK)
6350 !
6360 ! Sle(1,2,3) IS USED TO DENOTE CONVERSION OF VOLTAGE TO ENGLISH UNITS.
6370 Sl(1)=Sle(1)*Conlb*(-1.0) ! COMPRESSIVE LOAD IS NEGATIVE VOTLAGE
6380 Sl(2)=Sle(2)*Conlen
6390 Sl(3)=Sle(3)*Conlen*(-1.0) ! COMPRESSIVE STROKE SUPPLIES A NEGATIVE VOL
TAG

```



```

6410 !
6410 PRINT ""
6420 PRINT ""
6430 PRINT "YOUR ENTRIES HAVE PRODUCED THE FOLLOWING          CONVERSION DATA:"
6440 PRINT ""
6450 PRINT "FOR LOAD: ";S1(1);"NEWTON/VOLT  (";S1e(1);"Lbs/V)"
6460 PRINT ""
6470 PRINT "FOR COD: ";S1(2);"mm/V  (";S1e(2);"in/V)"
6480 PRINT ""
6490 PRINT "FOR DEFLECTION: ";S1(3);"mm/V  (";S1e(3);"in/V)"
6500 PRINT ""
6510 PRINT "WOULD YOU LIKE A HARD COPY?"
6520 INPUT H$
6530 IF H$="N" OR H$="NO" THEN 6630
6540 !
6550 PRINTER IS 706          ! TOGGLES PRINTER
6560 PRINT ""
6570 PRINT "          CONVERSION DATA"
6580 PRINT "FOR LOAD: ";S1(1);"N/V  (";S1e(1);"Lbs/V)"
6590 PRINT "FOR COD: ";S1(2);"mm/V  (";S1e(2);"in/V)"
6600 PRINT "FOR DEFLECTION: ";S1(3);"mm/V  (";S1e(3);"in/V)"
6610 PRINTER IS !          ! TOGGLES PRINTER
6620 !
6630 PRINT CHR$(12)
6640 !
6650 RETURN          ! RETURNS TO k-KEY SELECTION
6660 !
6670 !*****
6680 !
6690 Slope: ! LINEAR LEAST SQUARES FIT
6700 PRINT CHR$(12)          ! CLEAR CRT
6710 ! INITIALIZE VARIABLES
6720 P2=0          ! USED AS A COUNTER
6730 Sumx=0          ! SUM OF X VALUES
6740 Sumx2=0          ! SUM OF X SQUARED VALUES
6750 Sumy=0          ! SUM OF Y VALUES
6760 Sumy2=0          ! SUM OF Y SQUARED VALUES
6770 Sumxy=0          ! SUM OF THE PRODUCT
6780 FOR I=K1 TO K3          ! K1=INDEX OF FIRST, K3=INDEX OF LAST DATA POINT USED.
6790 ! TYPE OF PLOT
6800 IF C2=1 THEN 6840          ! LOAD vs COD
6810 IF C2=2 THEN 6880          ! LOAD vs DEFL
6820 IF C2=3 THEN 6920          ! J vs DELTA_a
6830 !
6840 X=Cod(I)
6850 Y=Lod(I)
6860 GOTO 6990
6870 !
6880 X=Defl(I)
6890 Y=Lod(I)
6900 GOTO 6990
6910 !
6920 X=Delta_a(I)
6930 Y=J9(I)
6940 !
6950 ! CHECK IF DATA POINT IS WITHIN BOUNDS
6960 IF Delta_a(I)<J9(I)/(2*Fs)+.15 THEN 7050          ! CHECKS LOWER LIMIT
6970 IF Delta_a(I)>J9(I)/(2*Fs)+1.5 THEN 7050          ! CHECKS UPPER LIMIT
6980 !
6990 Sumx=Sumx+X

```



```

7000      Sumy=Sumy+Y
7010      Sumx2=Sumx2+X*X
7020      Sumy2=Sumy2+Y*Y
7030      Sumxy=Sumxy+X*Y
7040      GOTO 7060          ! GET NEXT DATA POINT
7050      P2=P2+1          ! INCREMENTS COUNTER EACH TIME A POINT IS ELIMINATED.
7060      NEXT I
7070      K3=K3-P2          ! USED TO CALCULATE NUMBER OF DATA POINTS WITHIN BOUNDS.
7080      K4=K3-K1+1        ! K4=TOTAL # DATA POINTS USED IN CALC
7090      Qa1=Sumx2-Sumx*Sumx/K4
7100      Qa2=Sumxy-Sumx*Sumy/K4
7110      Qa3=Sumy2-Sumy*Sumy/K4
7120      !
7130      M=Qa2/Qa1          ! SLOPE
7140      !
7150      IF M<0 THEN 7430    ! IF SLOPE < 0, BAD DATA
7160      ! FROM DTNSRDC PROGRAM
7170      Q1=(K4*Sumx2-Sumx^2)/(K4*(K4-1))
7180      Q2=(K4*Sumy2-Sumy^2)/(K4*(K4-1))
7190      Q3=(K4-1)*(Q2-M*M*Q1)/(K4-2)
7200      Q4=SQR(Q3/(Q1*(K4-1)))
7210      !
7220      B=(Sumy-M*Sumx)/K4    ! INTERCEPT
7230      !
7240      Correl=M*SQR(Q1/Q2)
7250      !
7260      Qa4=SQR(ABS((Sumy2-B*Sumy-M*Sumxy)/(K4-2)))
7270      Sigmas=Qa4/SQR(ABS(Qa1))
7280      Sigmam=Sigmas*SQR(Sumx2/K4)
7290      Stiff=M              ! STIFF = SLOPE
7300      Compl=1/M            ! COD COMPLIANCE = 1/SLOPE
7310      !
7320      ! STUDENT t TEST
7330      U4=Q4
7340      T9=1.96
7350      IF K4>120 THEN 7410    ! RETURNS
7360      T9=2.1
7370      IF K4<20 THEN 7410    ! RETURNS
7380      N9=K4-2
7390      T9=N9/(-.617109+N9*.510239)
7400      !
7410      RETURN
7420      !
7430      PRINT "POOR DATA-- SLOPE < 0"
7440      M=333333.3
7450      Correl=0
7460      !
7470      RETURN          ! RETURNS TO Initial_a, Main_prog or R_curve ROUTINE (WHICHE
VER CALLED IT)
7480      !
7490      !*****
7500      !
7510      Data_file:          ! ESTABLISHES DATA FILE
7520      ! THE FILE YOU CREATE CAN BE READ BY THE "J_DATA" PROGRAM
7530      !
7540      ! NOTE: ANY CHANGES MADE TO THIS ROUTINE MAY REQUIRE SIMILAR CHANGES TO "
J_DATA" PROGRAM DUE
7550      ! TO DISK FORMATTING CONSULT HP MANUAL FOR ASSISTANCE.
7560      !
7570      PRINT CHR$(12)      ! CLAERS CRT

```



```

7580 PRINT "THIS ROUTINE WILL CREATE A DATA FILE ON DISK FOR THE TEST."
7590 PRINT ""
7600 PRINT "INSERT AN INITIALIZED DATA DISK AND ENTER FILE NAME (SAMPLE I
D IS SUGGESTED)."
```

```

7610 INPUT Name$
7620 PRINT ""
7630 PRINT "IS THIS A NEW FILE?"
7640 INPUT Q$
7650 IF Q$="N" OR Q$="NO" THEN 7680
7660 !
7670 CREATE BDAT Name$,6,40000
7680 ASSIGN @File TO Name$
7690 !
7700 PRINT ""
7710 PRINT "FOR RECORD PURPOSES THE FOLLOWING DATA IS ALSO RECORDED:"
7720 PRINT ""
7730 PRINT "ENTER THE DATE (MM-DAY-YEAR):"
7740 INPUT Data$(1)
7750 PRINT ""
7760 PRINT "ENTER THE TIME (HH:MM):"
7770 INPUT Data$(2)
7780 PRINT ""
7790 PRINT "ENTER THE OPERATOR'S NAME:"
7800 PRINT "      (UP TO 10 CHARACTERS)"
7810 INPUT Data$(3)
7820 PRINT ""
7830 PRINT "ENTER SPECIMEN ID:"
7840 PRINT "      (UP TO 10 CHARACTERS)"
7850 INPUT Data$(4)
7860 ! WRITE ON DISK
7870 FOR I=1 TO 4
7880   OUTPUT @File;Data$(I)[1;10]
7890 NEXT I
7900 !
7910 BEEP
7920 PRINT ""
7930 PRINT "DATA FILE HAS BEEN CREATED."
7940 !
7950 !
7960 RETURN      ! RETURNS TO k-KEY SELECTION
7970 !
7980 !*****
7990 !
8000 Stor_data:  ! WRITES DATA ON DISK
8010 !
8020 ! THE ITEMS STORED BY THIS ROUTINE CAN BE
8030 ! RECALLED USING THE "J_DATA" PROGRAM
8040 ! CARE MUST BE TAKEN IF ANY CHANGES ARE MADE TO THIS ROUTINE SUCH THAT SI
MILAR CHAGES ARE
8050 ! MADE TO THE "J_DATA" PROGRAM.
8060 !
8070 IF K2>0 THEN 8160      ! K2 IS UNLOADING COUNTER
8080   OUTPUT @File;A0(D2),Amin0(D2),Amax0(D2),Comp10(D2),Correl0(D2),K
8090 !
8100 PRINT ""
8110 PRINT ""
8120 PRINT "INITIAL CRACK LENGTH (a0) INFORMATION FROM MEASUREMENT #";
D2
8130 PRINT "IS NOW IN DISK FILE ";Name$
8140 !

```



```

3150 IF K2=0 THEN 8220 ! SKIP IF THIS WAS a0 MEASUREMENT
3160 OUTPUT @File:K2,A1(K2),Delta_a(K2),K,L,Correl,Compl,Amin,Amx,Area9(K2
),J9(K2)
3170 OUTPUT @File:Mdef1(K2),Codiff,K0,K1
3180 !
3190 PRINT ""
3200 PRINT "UNLOADING INFORMATION IS NOW IN DISK FILE ";Name$
3210 !
3220 BEEP
3230 ! WAIT 3 ! ALLOWS A PAUSE SO MESSAGE IS PRESENTED ON THE CRT
3240 !
3250 !
3260 RETURN ! RETURNS TO Initial_a OR Main_prog
3270 !
3280 !*****
3290 !
3300 Take_data: ! THIS ROUTINE IS USED TO TAKE DATA DURING THE ACTUAL TEST.
3310 !
3320 I=K ! INDEX
3330 OUTPUT Dvm:"AI1 VT1" ! READS LOAD
3340 ENTER Dvm:Lod(I)
3350 Lod(I)=Lod(I)*S1(1)
3360 !
3370 OUTPUT Dvm:"AI2 VT1" ! READS COD
3380 ENTER Dvm:Cod(I)
3390 Cod(I)=Cod(I)*S1(2)
3400 !
3410 OUTPUT Dvm:"AI3 VT1" ! READS DEFLECTION
3420 ENTER Dvm:Defl(I)
3430 Defl(I)=Defl(I)*S1(3)
3440 !
3450 GOSUB Correct_defl ! DETERMINE CORRECTION FACTOR FOR SYSTEM COMPLIA
NCE
3460 !
3470 Defl(I)=Defl(I)-Totcor
3480 !
3490 ! PLOT THE DATA POINT
3500 VIEWPORT 13,100=RATIO,10,90
3510 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3520 IF C2=2 THEN 8550
3530 PLOT Cod(I),Lod(I)
3540 GOTO 8560
3550 PLOT Defl(I),Lod(I)
3560 !
3570 !
3580 RETURN ! RETURNS TO Main_prog
3590 !
3600 !*****
3610 !
3620 J_calc: ! CALCULATES J WITH CRACK GROWTH CORRECTION ERNST MODEL (USED BY D
TNSRDC)
3630 !
3640 E5=2
3650 ! CALCULATE J FOR FIRST (1st) UNLOADING
3660 IF K2>1 THEN 8690
3670 J6=J7+E5/(W-A1(K2))*Area9(K2)/Bmin
3680 GOTO 8730
3690 J6=J7+E5/(W-A1(K2))*(Area9(K2)-Area9(K2-1))/Bmin
3700 ! IF DELTA_a < 0.254mm DO NOT USE CRACK GROWTH CORRECTION
3710 IF Delta_a(K2)<.254 THEN 8730

```



```

8720 J6=J6*(1-1/(W-A1(K2))*(A1(K2)-A1(K2-1))) ! CORRECTS FOR CRACK GROWTH (A
STM E813-81)
8730 J7=J6
8740 !
8750 J9(K2)=J6 ! STORES CURRENT J VALUE IN J9 ARRAY.
8760 !
8770 RETURN ! RETURNS TO Main_prog
8780 !
8790 ! *****
8800 !
8810 Main_prog: ! THIS IS THE MAIN PROGRAM FOR THE J-INTEGRAL TEST.
8820 !
8830 PRINT CHR$(12) ! CLEARS CRT
8840 PRINT ""
8850 PRINT "ENSURE YOU HAVE COMPLETED THE FOLLOWING ITEMS BEFORE PROCE
EDING:"
8860 PRINT " 1. ENTERED SPECIMEN DATA."
8870 PRINT " 2. ENTERED CONVERSION DATA."
8880 PRINT " 3. SET UP INTERACTIVE PLOTTER."
8890 PRINT " 4. OBTAINED INITIAL CRACK LENGTH."
8900 PRINT ""
8910 PRINT " ARE YOU READY?"
8920 INPUT H$
8930 IF H$="NO" OR H$="N" THEN 10530 ! RETURNS TO WAIT FOR k-KEY SELECTION
8940 PRINT ""
8950 PRINT ""
8960 PRINT "WHAT IS YOUR EXPECTED MAXIMUM LOAD IN NEWTONS?"
8970 INPUT Pmax
8980 Lod5=.1*Pmax ! USED TO SIGNAL TURN AROUND FROM UNLOADING
8990 !
9000 PRINT "THE TEST SHOULD START WITH NEAR ZERO (0) LOAD WITH THE MTS IN 'STR
OKE' CONTROL."
9010 PRINT ""
9020 PRINT "ENSURE THIS IS DONE."
9030 PRINT ""
9040 PRINT "WHEN YOU ARE READY PRESS 'ENTER' OR 'CONTINUE' KEY AND START THE M
TS MACHINE."
9050 INPUT H$
9060 PRINT CHR$(12) ! CLEARS CRT
9070 !
9080 !
9090 ! INITIALIZE VARIABLES
9100 Area=0 ! AREA UNDER LOAD vs DEFLECTION CURVE DTNSRDC (I8)
9110 Area9(1)=0 ! AREA BENEATH SPECIFIC LOD vs DEFL (DTNSRDC I9(K2))
9120 K=K ! CURRENT INDEX (AFTER OBTAINING INITIAL CRACK LENGTH)
9130 I=K ! INDEX OF FIRST TEST DATA POINT
9140 K0=K ! WHERE TEST DATA STARTS
9150 K1=0 ! LOWER INDEX FOR SLOPE CALC
9160 K2=0 ! A COUNTER (K2) NUMBER OF UNLOADINGS
9170 K3=0 ! UPPER INDEX FOR SLOPE CALC
9180 L=1 ! A COUNTER DTNSRDC (L) " " DATA POINTS TAKEN DURING
UNLOADING
9190 Lod1=0 ! TEMP LOAD " (P1) USED IN AREA CALC
9200 Lod2=0 ! TEMP LOAD " (P2) " " "
9210 Lod5=.1*Pmax ! " (P5) USED FOR TURN AROUND SIGNAL
9220 Lod9=0 ! MAX LOAD " (P9)
9230 Cod1=0 ! TEMP COD " (D1)
9240 Cod2=0 ! TEMP COD " (D2)
9250 Cod4=0 ! TEMP COD " (C4)

```



```

9260 Cod9=0      ! MAX COD      "      (D9)
9270 Codiff=0   ! COD DIFFERENCE "      (D3)
9280 Defl1=0    ! TEMP DEFL    "      (D4) USED IN AREA CALC
9290 Defl2=0    ! TEMP DEFL    "      (D5) " " " "
9300 J6=0       ! JI FROM CURRENT UNLOAD
9310 J7=0       ! JI FROM PREVIOUS UNLOAD DTNSDRC (J7)
9320 I1=0       ! FLAG (0=LOADING, 1=UNLOADING)
9330 F1=0       ! FLAG (F1=999 ENDS TEST)
9340 !
9350 !
9360 PRINT ""
9370 !
9380 IF F1=999 THEN GOSUB End_test
9390 !
9400 GOSUB Take_data
9410 Defl16=Defl1(I)
9420 Lod7=Lod(I)
9430 Lod2=Lod(I)
9440 Defl12=Defl1(I)
9450 Cod2=Cod(I)
9460 !
9470 ! TEST CONDITIONS OF DATA POINT JUST TAKEN
9480 IF (K-K0)<20 THEN 10430 ! CALC AREA & TAKE MORE DATA
9490 Codiff=Cod2-Cod1
9500 IF Codiff<-3.0E-4 THEN 9540 ! IF CODIFF IS (-) CHECK IF LOADING OR UNLO
ADING
9510 IF I1=0 THEN 10430 ! IF LOADING CALC AREA & TAKE MORE DATA
9520 IF Cod2>Cod9 THEN 9600 ! IF TRUE CHECK IF GOOD UNLOADING
9530 GOTO 10340 ! DISREGARD UPPER 2% OF UNLOADING CURVE
9540 IF I1<>0 THEN 10340 ! IF UNLOADING CHECK IF ON UPPER 2% OF CURVE
9550 Lod9=Lod2 ! IF LOADING MAKE CURRENT LOAD = MAXIMUM LOAD
9560 Cod9=Cod2 ! MAKE CURRENT COD = MAX COD
9570 Defl9=Defl2 ! MAKE CURRENT DEFL = MAX DEFL
9580 I1=1 ! MUST BE UNLOADING
9590 GOTO 10340 ! TEST IF UPPER 2% OF UNLOADING
9600 IF L<5 THEN 10290 ! BAD UNLOADING, SET I1=1
9610 K1=K-L ! SETS LOWER INDEX FOR SLOPE CALCULATION.
9620 K3=K1+L ! SETS UPPER INDEX FOR SLOPE CALCULATION.
9630 PENUP
9640 !
9650 K2=K2+1 ! INCREMENT UNLOADING COUNTER
9660 !
9670 GOSUB Slope ! IF GOOD UNLOADING
9680 Stiff2=Stiff
9690 GOSUB Crack_length ! CALC CRACK LENGTH
9700 A1(K2)=Crckl ! CURRENT CRACK LENGTH
9710 Delta_a(K2)=A1(K2)-A1 ! DETERMINE CRACK GROWTH
9720 !
9730 ! NOTE: A1 = INITIAL CRACK LENGTH; ASSIGNED IN Initial_a ROUTINE.
9740 !
9750 Crckl4=Crckl
9760 PRINT " ---- UNLOADING #";K2;" ----"
9770 ! PRINT ""
9780 PRINT "CRACK LENGTH =";A1(K2);"mm"
9790 PRINT "DELTA_a =";Delta_a(K2);"mm"
9800 PRINT "TOTAL # DATA POINTS = ";K
9810 PRINT "# DATA POINTS THIS UNLOADING =";L
9820 PRINT "CORRELATION =";Correl
9830 PRINT "COD COMPLIANCE =";Compl;"mm/N"

```



```

9840 !
9850 Area9(K2)=Area
9860 !
9870 ! CALCULATE 95% CONFIDENCE INTERVAL
9880 Stiff=Stiff+T9*U4
9890 GOSUB Crack_length
9900 Amax=Crck1
9910 Stiff=Stiff-2*T9*U4
9920 GOSUB Crack_length
9930 Stiff=Stiff2
9940 Amin=Crck1
9950 PRINT ""
9960 PRINT "95% CONFIDENCE INTERVAL ON CRACK LENGTH FROM ";Amin;"TO";Amax
9970 !
9980 GOSUB J_calc ! CALC J (USES J-ERNST MODEL)
9990 !
10000 Mdefl(K2)=Defl(K) ! MAX DEFLECTION
10010 !
10020 ! PRINT ""
10030 PRINT "AREA =";Area9(K2);"N*mm"
10040 PRINT "J =";J9(K2);"KJ/m^2"
10050 PRINT "LOAD LINE DEFLECTION =";Mdefl(K2);"mm"
10060 PRINT "CHANGE IN COD =";Codiff;"mm"
10070 PRINT "K0=";K0;" K1=";K1
10080 !
10090 !
10100 GOSUB Prt_results ! PRINTS RESULTS ON PRINTER
10110 !
10120 ! DATA POINTS CAN BE PRESENTED FOR REVIEW BY SIMPLY REMOVING THE REMARK C
HARACTER (!).
10130 PRINT ""
10140 ! PRINT " PT # LOAD(N) DEFLECTION(mm) COD(mm)"
10150 ! FOR I=(K1-1) TO K
10160 ! PRINT USING 9170;I,Lod(I),Defl(I),Cod(I)
10170 ! IMAGE 4D,4X,5D.D,6X,DD.6D.7X,DD.6D
10180 ! NEXT I
10190 ! WAIT 5 ! PAUSE TO ALLOW VIEWING
10200 !
10210 !
10220 GOSUB Stor_data ! STORES INFORMATION ON DISK
10230 !
10240 !
10250 IF Crck14-A1>0 THEN 10290
10260 PRINT ""
10270 PRINT " NO CRACK EXTENSION THIS POINT."
10280 PRINT ""
10290 I1=0
10300 L=1
10310 ! IF L=1 THEN K1=K ! SETS LOWER INDEX FOR SLOPE CALCULATION AT CURRENT
K
10320 GOTO 10360
10330 IF Cod2<Cod1 THEN 10440 ! GET MORE DATA
10340 IF Lod2>.98*Lod9 THEN 10440 ! DISREGARD UPPER 2% OF UNLOADING & GET MO
RE DATA
10350 L=L+1 ! INCREMENT DATA POINT COUNTER
10360 IF Lod2>Lod9-Lod5 THEN 10440 ! IF TRUE GET MORE DATA
10370 BEEP ! SENDS OUT BEEP
10380 BEEP ! AS TURN AROUND
10390 BEEP ! SIGNAL TO BEGIN RELOADING
10400 GOTO 10440 ! RESUME TAKING AND TEST DATA
10410 !
10420 ! CALCULATE AREA UNDER LOAD vs DEFLECTION CURVE

```



```

10430 Area=Area+(Defl2-Defl1)*(Lod2+Lod1)/2
10440 Lod1=Lod2
10450 K=K+1      ! INCREMENT TOTAL # DATA POINTS COUNTER
10460 Cod1=Cod2
10470 Defl1=Defl2
10480 !
10490 GOTO 9380   ! LOOP BACK CHECK IF TEST IS
10500 !           OVER, IF NOT TAKE MORE DATA.
10510 !
10520 !
10530 RETURN      ! NEVER REACH THIS BUT ROUTINE WOULD NOT BE VALID WITHOUT IT
10540 !
10550 !*****
10560 Prt_results: ! PRINTS TEST INFORMATION WHILE PROGRAM IS RUNNING
10570 PRINTER IS 706 ! TOGGLES PRINTER
10580 PRINT ""
10590 PRINT "      ---- UNLOADING #";K2;" ----"
10600 PRINT ""
10610 PRINT "CRACK LENGTH =";A1(K2);"mm      DELTA _a =";Delta_a(K2);"mm"
10620 PRINT "95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM";Amin;" TO";Amax
10630 PRINT ""
10640 PRINT "TOTAL # DATA POINTS =";K;"      # DATA POINTS THIS UNLOADING =";L
10650 PRINT "CORRELATION =";Correl
10660 PRINT "COD COMPLIANCE =";Compl;"mm/N"
10670 PRINT ""
10680 PRINT "AREA =";Area9(K2);"N*mm"
10690 PRINT "J =";J9(K2);"KJ/m^2"
10700 PRINT "MAX LOAD LINE DEFLECTION =";Mdefl(K2);"mm"
10710 PRINT "CHANGE IN COD =";Codiff;"mm"
10720 !
10730 PRINT ""
10740 PRINTER IS 1      ! TOGGLES PRINTER TO CRT
10750 !
10760 RETURN           ! RETURNS TO Main_prog
10770 !
10780 !*****
10790 !
10800 Stor_arrays: ! STORES ARRAYS (Lod,Defl,Cod) ON DISK
10810 !
10820 ! THE ARRAYS CAN BE RECALLED LATER USING
10830 ! THE "J_DATA" PROGRAM.
10840 !
10850     OUTPUT @File;Lod(*),END
10860     OUTPUT @File;Defl(*),END
10870     OUTPUT @File;Cod(*),END
10880 !
10890 BEEP
10900 !
10910 !
10920 RETURN           ! RETURNS TO End_test
10930 !
10940 !*****
10950 !
10960 End_test:      ! ENDS TEST
10970 !
10980 PRINT CHR$(12)
10990 !
11000 !
11010 GOSUB Stor_arrays
11020 !

```



```

11030 PRINT "DATA HAS BEEN STORED ON DISK IN FILE ";Name$
11040 !
11050 GOSUB R_curve
11060 !
11070 PRINT ""
11080 PRINT "  TEST IS OVER!!"
11090 PRINT ""
11100 PRINT ""
11110 PRINT ""
11120 PRINT ""
11130 PRINT ""
11140 PRINT "      TEST IS OVER!"
11150 PRINT ""
11160 PRINT ""
11170 PRINT ""
11180 PRINT ""
11190 PRINT ""
11200 PRINT "      TEST IS OVER!"
11210 !
11220 !
11230 GOTO 12590      ! GO TO END STATEMENT
11240 !
11250 RETURN      ! NEVER REACH THIS POINT BUT ROUTINE WOULD NOT BE VALID WITHOUT
IT
11260 !
11270 !*****
11280 !
11290 R_curve:  ! J vs DELTA_a DATA  IS PRESENTED FOR PLOTTING
11300 !
11310 PRINT ""
11320 !
11330 ! ALL (*) STATEMENTS WILL ALLOW DIRECT INPUT OF Delta_a(I) vs J9(I) DATA
11340 ! YOU MUST REMOVE [!(*)] FROM BEGINNING OF EACH LINE TO ACTIVATE
11350 !(*) PRINT "INPUT THE # OF UNLOADINGS"
11360 !(*) INPUT K2
11370 !(*) PRINT "ENTER DELTA_A(I),J9(I)"
11380 PRINT "UNLOADING #   DELTA_a(mm)      J(kJ/m^2)"
11390 FOR I=1 TO K2
11400   !(*) INPUT Delta_a(I),J9(I)
11410   PRINT USING 11420:I,Delta_a(I),J9(I)
11420   IMAGE 6X,3D,4X,DD.6D,5X,6D.D
11430 NEXT I
11440 PRINT ""
11450 PRINT "DO YOU WANT A HARD COPY?"
11460 INPUT H$
11470 IF H$="N" OR H$="NO" THEN 11680
11480 !
11490 PRINTER IS 706      ! TOGGLES TO THERMAL PRINTER
11500 PRINT "UNLOADING #   DELTA_a(mm)      J(kJ/m^2)"
11510 FOR I=1 TO K2
11520   PRINT USING 11420:I,Delta_a(I),J9(I)
11530 NEXT I
11540 PRINTER IS 1      ! RETURNS TO CRT AS PRINTER
11550 !
11560 !(*) PRINT "ARE ALL OKAY?"
11570 !(*) INPUT G$
11580 !(*) IF G$="Y" THEN 11582
11590 !(*) PRINT "INPUT I (INDEX) OF BAD #"
11600 !(*) INPUT L1
11610 !(*) PRINT "INPUT VALUES OF DELTA_A(I) AND J9(I)"

```



```

11620 !(*) INPUT Delta_a(L1),J9(L1)
11630 !(*) PRINT "ARE YOU OK"
11640 !(*) INPUT Eee$
11650 !(*) IF Eee$="N" THEN GOTO 11574
11660 ! END OF (*) CHANGES REQUIRED FOR DIRECT INPUT OF DELTA_A(I) vs J9(I) DAT
A
11670 !
11680 PRINT ""
11690 PRINT "DO YOU WANT A PLOT OF J vs DELTA_a?"
11700 INPUT RS
11710 IF RS="N" OR RS="NO" THEN 12550
11720 PRINT ""
11730 PRINT "WHEN THE PLOTTER IS READY (NEW GRAPH PAPER INSTALLED) PRESS 'ENTER
' OR 'CONTINUE' KEY"
11740 INPUT Cs
11750 !
11760 GOSUB Setup_plotter
11770 !
11780 ! PLOT THE DATA THE DATA POINTS
11790 VIEWPORT 13,100*RATIO,10,90
11800 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
11810 FOR I=1 TO K2
11820     X=Delta_a(I)
11830     Y=J9(I)
11840     MOVE X-X3*.005,Y+Y3*.005      ! DRAWS A
11850     DRAW X+X3*.005,Y-Y3*.005     ! SMALL X
11860     MOVE X+X3*.005,Y+Y3*.005     ! FOR DATA
11870     DRAW X-X3*.005,Y-Y3*.005     ! POINT
11880 NEXT I
11890 !
11900 ! PLOT THE BLUNTING LINE
11910 VIEWPORT 13,100*RATIO,10,90
11920 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
11930     Bly=Y2(C2)-Y3/8      ! TAKES LINE TO 7/8 OF Ymax
11940     Blx=Bly/(2*Fs)*1000  ! DELTA_a = J/2*Fs
11950     MOVE 0,0
11960     DRAW Blx,Bly
11970 !
11980     Blminx=Blx+.15      ! DRAWS LOWER BOUNDS
11990     MOVE .15,0
12000     LINE TYPE 4
12010     DRAW Blminx,Bly
12020 !
12030     Blmaxx=Blx+1.5      ! DRAWS UPPER BOUNDS
12040     MOVE 1.5,0
12050     LINE TYPE 4
12060     DRAW Blmaxx,Bly
12070     PENUP
12080 !
12090 K1=1      ! LOWER INDEX FOR LEAST SQUARES FIT
12100 K3=K2    ! UPPER INDEX
12110 GOSUB Slope
12120 !
12130 ! PLOT THE LINE OBTAINED
12140 VIEWPORT 13,100*RATIO,10,90
12150 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
12160     Xplt=X2(C2)-X3/8      ! TAKES LINE TO 7/8 OF Xmax
12170     Yplt=Xplt*M+B
12180     MOVE 0,B
12190     LINE TYPE 6

```



```

12200      DRAW Xplt,Yplt
12210      PENUF
12220      PRINT ""
12230      PRINT "ONLY DATA WITHIN BOUNDS IS USED"
12240      PRINT "FOR LEAST SQUARES FIT."
12250      PRINT ""
12260      PRINT "SLOPE=";M;" INTERCEPT=";B
12270      PRINT "CORREL=";Correl
12280      PRINT "NUMBER OF DATA POINTS USED:";K4
12290      !
12300      PRINTER IS 706          ! TOGGLES PRINTER
12310      PRINT ""
12320      PRINT ""
12330      PRINT "DATA FROM J vs DELTA_a PLOT"
12340      PRINT ""
12350      PRINT "SLOPE =" ;M;"   Y-INTERCEPT =" ;B
12360      PRINT "CORRELATION =" ;Correl;"   FROM";K4;" DATA POINTS."
12370      PRINTER IS 1          ! TOGGLES PRINTER
12380      !
12390      ! FIND THE INTERSECTION. HENCE J(1c).
12400      ! SOLVE BOTH EQUATIONS SIMULTANEOUSLY
12410      !  $J = M \cdot (\Delta_a) + B = (\Delta_a) \cdot (2 \cdot F_s)$  HENCE:
12420       $J1c = (B/M) / (1/M - (1000/(2 \cdot F_s)))$ 
12430      PRINT ""
12440      PRINT "      J1c =" ;J1c
12450      PRINTER IS 706          ! TOGGLES PRINTER
12460      PRINT ""
12470      PRINT "      J1c =" ;J1c
12480      PRINT ""
12490      PRINT ""
12500      PRINT " TEST IS OVER!"
12510      PRINTER IS 1          ! TOGGLES PRINTER
12520      !
12530      ! GOTO 12100          ! GO TO END STATEMENT
12540      !
12550      RETURN          ! RETURNS TO End_test ROUTINE
12560      !
12570      ! *****
12580      !
12590      END          ! END OF TEST AND PROGRAM
12600      !
12610      ! *****
12620      !
12630      SUB Stop_test          ! STOPS TEST
12640      !      k9-KEY ACTS AS PROGRAM INTERRUPT
12650      ! k9-KEY IS NOT LABELED, BUT IS ASSIGNED A HIGHER PRIORITY TI INTERRUPT P
ROGRAM
12660      !
12670      COM /J_intgl/ F1
12680      F1=999          ! SETS STOP FLAG
12690      !
12700      SUBEND
12710      ! *****

```


APPENDIX F

J_DATA LISTING

```
10      !           J_DATA PROGRAM
20      ! THIS PROGRAM WILL ALLOW YOU TO READ A DATA
30      ! FILE CREATED BY "J_INTGL". YOU MUST KNOW
40      ! HOW MANY UNLOADINGS WERE RECORDED DURING
50      ! THE TEST TO USE THIS PROGRAM.
60      !
70      ! PROGRAM WAS WRITTEN BY:
80      !   LCDR W.K. TRITCHLER
90      ! VERSION 1.0      DATE 11/83
100     !
110     !
120     !
130     DIM Data$(1:4)(101)
140     DIM Lod(8000).Defl(8000).Cod(3000)
150     DIM A1(100).Area9(100).Delta_a(100)
160     DIM Mdefl(100).J9(100)
170     !
180     PRINT CHR$(12)      ! CLEARS CRT
190     !
200     DUMP DEVICE IS 706
210     PRINT "WHAT DATA FILE DO YOU WISH TO READ?"
220     INPUT Name$
230     ASSIGN @File TO Name$
240     FOR I=1 TO 4
250         ENTER @File;Data$(I)(1:101)
260     NEXT I
270     PRINT ""
280     PRINT "J-INTEGRAL TEST OF ";Data$(4);"BY: ";Data$(3)
290     PRINT ""
300     PRINT "DATE: ";Data$(1);"      TIME: ";Data$(2)
310     ENTER @File;Crck1,Amin,Amx,Compl,Correl,K
320     PRINT ""
330     PRINT ""
340     PRINT ""
350     PRINT "a0=";Crck1,"WITH 95% CONFIDENCE INTERVAL FROM";Amin;"      TO";Amx
360     PRINT ""
370     PRINT "FROM COMPLIANCE - ";Compl
380     PRINT ""
390     PRINT "CORRELATION=";Correl;"FROM";K;"DATA POINTS"
400     PRINT ""
410     PRINT "DO YOU WANT A HARD COPY OF THIS INFORMATION?"
420     INPUT G$
430     IF G$="N" OR G$="NO" THEN 450
440     DUMP ALPHA
450     PRINT ""
460     PRINT "INPUT THE NUMBER OF UNLOADINGS THAT WERE RECORDED DURING THE TEST."
470     INPUT C1      ! WILL BE USED AS COUNTER
480     FOR I=1 TO C1
490         ENTER @File;K2,A1(K2),Delta_a(K2),K,L,Correl,Compl,Amin,Amx,Area9(K2),
J9(K2)
500         ENTER @File;Mdefl(K2),Codiff,K0,K1
510         GOSUB Prt_results      ! DISPLAYS INFO
520         PRINT ""
530         PRINT "DO YOU WANT A HARD COPY?"
540         INPUT Q$
550         IF Q$="N" OR Q$="NO" THEN 580
560         PRINTER IS 706
570         GOSUB Prt_results      ! WILL NOW PRINT INFO
580     NEXT I
590     PRINT "DO YOU WANT A LISTING OF THE DATA POINTS?"
```



```

600 INPUT E$
610 IF E$="N" OR E$="NO" THEN 830
620 PRINT ""
630 PRINT "PT #      LOAD (N)      DEFLECTION (mm)      COD (mm)"
640 ENTER %File:Lod(*),Defl(*),Cod(*)
650 FOR I=1 TO K
660     PRINT USING 670:I.Lod(I),Defl(I),Cod(I)
670     IMAGE X,40.3X,SD.D,8X,D.6D.8X,D.6D
680 NEXT I
690 PRINT ""
700 PRINT "DO YOU WANT A HARD COPY?"
710 INPUT H$
720 IF H$="N" OR H$="NO" THEN 830
730 PRINTER IS 706
740 PRINT "DATA FROM a0 FOR: ";Data$(4);"BY: ";Data$(3)
750 PRINT ""
760 PRINT "TESTED ON: ";Data$(1);"TIME: ";Data$(2)
770 PRINT ""
780 PRINT "PT #      LOAD (N)      DEFLECTION (mm)      COD (mm)"
790 FOR I=1 TO K
800     PRINT USING 670:I.Lod(I),Defl(I),Cod(I)
810 NEXT I
820 PRINTER IS !
830 PRINT CHR$(12)          ! CLEARS CRT
840 PRINT "DO YOU WISH TO PLOT ANY DATA?"
850 INPUT P$
860 IF E$="Y" OR E$="YES" THEN 880 ! OTHERWISE MUST NOW READ DATA POINTS OFF
DISKETTE
870 ENTER %File:Lod(*),Defl(*),Cod(*)
880 IF P$="Y" OR P$="YES" THEN GOSUB Setup_plotter
890 PRINT "DO YOU WANT ANOTHER PLOT?"
900 INPUT A$
910 IF A$="Y" OR A$="YES" THEN GOSUB Setup_plotter
920 PRINT "DO YOU WANT ANOTHER PLOT?"
930 INPUT F$
940 IF F$="Y" OR F$="YES" THEN GOSUB Setup_plotter
950 PRINT "      PROGRAM IS OVER!!!"
960 PRINT ""
970 PRINT ""
980 PRINT ""
990 PRINT ""
1000 PRINT ""
1010 PRINT "      PROGRAM IS OVER!"
1020 PRINT ""
1030 PRINT ""
1040 PRINT ""
1050 PRINT ""
1060 PRINT ""
1070 PRINT "      PROGRAM IS OVER!"
1080 !
1090 GOTO 1290
1100 !
1110 !*****
1120 !
1130 Prt_results: ! DISPLAYS OR PRINTS UNLOADING INFORMATION
1140 PRINT ""
1150 PRINT "FROM UNLOADING #":K2:"RECORDED":L:"DATA POINTS"
1160 PRINT "COD COMPLIANCE =":Compl:"mm/N      CORRELATION =":Correl
1170 PRINT "CRACK LENGTH =":Al(K2):"mm      DELTA_A =":Delta_a(K2):"mm"
1180 PRINT "95% CONFIDENCE INTERVAL FROM":Amin:"mm TO":Amax:"mm"

```



```

1190 PRINT "AREA =" ; Area9(K2) ; "N*mm   J =" ; J9(K2) ; "KPa*mm"
1200 PRINT "DATA POINT INDEXES FROM" ; K1 ; "TO" ; K2 ; " WERE USED."
1210 PRINT ""
1220 PRINTER IS 1
1230 !
1240 RETURN
1250 !
1260 !-----
1270 !
1280 Setup_plotter:      ! SET UP PLOTTER
1290 ! YOU CAN CHOOSE BETWEEN THREE DIFFERENT PLOTS
1300 PRINT CHR$(12)      ! CLEARS CRT
1310 DIM TS(80),XS(80),YS(80)
1320 GCLEAR
1330 GINIT
1340 GRAPHICS ON
1350 PLOTTER IS 3,"INTERNAL"    ! PLOTS ON CRT
1360 PRINT "TYPE OF PLOT:"
1370 PRINT "      1.  LOAD vs COD"
1380 PRINT "      2.  LOAD vs DEFLECTION"
1390 PRINT "      3.  J vs CRACK EXTENSION"
1400 PRINT "ENTER THE # OF THE PLOT YOU DESIRE"
1410 INPUT C2
1420 PRINT ""
1430 PRINT ""
1440 IF C2=1 THEN 1470
1450 IF C2=2 THEN 1520
1460 IF C2=3 THEN 1570
1470 TS="PLOT of LOAD vs COD for "&Data$(4)
1480 PRINT TS
1490 XS="COD (mm)"
1500 YS="LOAD (N)"
1510 GOTO 1610
1520 TS="PLOT of LOAD vs DEFLECTION for "&Data$(4)
1530 PRINT TS
1540 XS="DEFLECTION (mm)"
1550 YS="LOAD (N)"
1560 GOTO 1610
1570 TS="PLOT OF J vs CRACK EXTENSION for "&Data$(4)
1580 PRINT TS
1590 XS="DELTA_a (mm)"
1600 YS="J (kJ/m^2)"
1610 PRINT ""
1620 PRINT "USING METRIC UNITS (mm,N,kJ/m^2.etc.):"
1630 PRINT "ENTER THE Xmin,Xmax,Ymin,Ymax"
1640 INPUT X1(C2),X2(C2),Y1(C2),Y2(C2)
1650 X3=X2(C2)-X1(C2)
1660 Y3=Y2(C2)-Y1(C2)
1670 VIEWPORT 13,100=RATIO,10,90
1680 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
1690 PRINT ""
1700 PRINT "INPUT DELTA_X AND DELTA_Y LABEL INTERVAL"
1710 PRINT "FOR THE TWO AXES:"
1720 INPUT X4,Y4
1730 PRINT ""
1740 PRINT "DO YOU WISH TO HAVE A GRID OVERLAY?"
1750 INPUT G$
1760 IF G$="N" OR G$="NO" THEN 1800
1770 PRINT ""
1780 PRINT "INPUT GRID LINES PER DELTA LABEL:"

```



```

1790 INPUT B0
1800 PRINT "PRESS 'ENTER' OR 'CONTINUE' KEY TO PLOT"
1810 INPUT H$ ! DUMMY VARIABLE
1820 PRINT CHR$(12) ! CLEARS CRT
1830 IF G$="N" OR G$="NO" THEN 1970
1840 FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
1850     MOVE I,Y1(C2)
1860     DRAW I,Y2(C2)
1870 NEXT I
1880 FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
1890     MOVE X1(C2),I
1900     DRAW X2(C2),I
1910 NEXT I
1920 GOTO 1970
1930 IF G$="Y" OR G$="YES" THEN 1970
1940 MOVE X2(C2),Y1(C2)
1950 DRAW X2(C2),Y2(C2)
1960 DRAW X1(C2),Y2(C2)
1970 CLIP ON
1980 AXES X4,Y4,X1(C2),Y1(C2)
1990 CLIP OFF
2000 VIEWPORT 13,100=RATIO,5,90
2010 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2020 LORG 4
2030 CSIZE 3,.5
2040 FOR X=X1(C2) TO X2(C2) STEP X4
2050     CLIP OFF
2060     MOVE X,Y1(C2)
2070     LABEL USING "K";X ! PLOTS X-DIGITS
2080 NEXT X
2090 VIEWPORT 4,100=RATIO,10,90
2100 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2110 LORG 2
2120 FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2130     CLIP OFF
2140     MOVE X1(C2),Y
2150     LABEL USING "K";Y
2160 NEXT Y
2170 VIEWPORT 0,100=RATIO,0,100
2180 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2190 CSIZE 5
2200 LORG 6 ! PLOTS TITLE
2210     MOVE X2(C2)/2,Y2(C2)
2220     LABEL T$
2230 DEG
2240 LDIR 90
2250 CSIZE 4,.7
2260     MOVE X1(C2),Y2(C2)/2
2270     LABEL Y$ ! PLOTS Y-AXIS LABEL
2280 LORG 4
2290 LDIR 0
2300     MOVE X2(C2)/2,Y1(C2)
2310     LABEL X$ ! PLOTS X-AXIS LABEL
2320 !
2330 PRINT ""
2340 PRINT ""
2350 PRINT ""
2360 PRINT ""
2370 PRINT " IS THE PLOT (AXES AND LABELS) OK?"
2380 PRINT ""

```



```

2390 PRINT "          NOTE: IF YOU ANSWER YES OR Y"
2400 PRINT "          PLOT WILL BE SENT TO"
2410 PRINT "          EXTERNAL PLOTTER"
2420 INPUT Fs
2430 IF Fs="N" OR Fs="NO" THEN GOSUB Setup_plotter ! REDO PLOTTER SETUP
2440 !
2450 GCLEAR ! CLEARS PLOT FROM CRT
2460 !
2470 GOSUB Ext_plotter
2480 !
2490 PENUP
2500 MOVE 0,0
2510 !
2520 GOSUB Plot_data
2530 !
2540 RETURN
2550 !
2560 !*****
2570 !
2580 Ext_plotter: ! DUMPS PLOTTER SETUP ON EXTERNAL HP-7225B PLOTTER
2590 PLOTTER IS 705,"HPGL"
2600 VIEWPORT 13,100=RATIO,10,90
2610 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2620 IF Gs="N" OR Gs="NO" THEN 2730
2630 FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
2640     MOVE I,Y1(C2)
2650     DRAW I,Y2(C2)
2660 NEXT I
2670 FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
2680     MOVE X1(C2),I
2690     DRAW X2(C2),I
2700 NEXT I
2710 GOTO 2760
2720 IF Gs="Y" OR Gs="YES" THEN 2760
2730 MOVE X2(C2),Y1(C2)
2740 DRAW X2(C2),Y2(C2)
2750 DRAW X1(C2),Y2(C2)
2760 CLIP ON
2770 AXES X4,Y4,X1(C2),Y1(C2)
2780 CLIP OFF
2790 VIEWPORT 13,100=RATIO,5,90
2800 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2810 LORG 4
2820 CSIZE 3,.6
2830 FOR X=X1(C2) TO X2(C2) STEP X4
2840     CLIP OFF
2850     MOVE X,Y1(C2)
2860     LABEL USING "K";X
2870 NEXT X
2880 VIEWPORT 4,100=RATIO,10,90
2890 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2900 LORG 2
2910 FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2920     CLIP OFF
2930     MOVE X1(C2),Y
2940     LABEL USING "K";Y
2950 NEXT Y
2960 VIEWPORT 0,100=RATIO,0,100
2970 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2980 LORG 2

```



```

2990 CSIZE 5
3000 LORG 6
3010 MOVE X2(C2)/2,Y2(C2)
3020 LABEL T$
3030 DEG
3040 LDIR 90
3050 CSIZE 4,.7
3060 MOVE X1(C2),Y2(C2)/2
3070 LABEL Y$
3080 LORG 4
3090 LDIR 0
3100 MOVE X2(C2)/2,Y1(C2)
3110 LABEL X$
3120 !
3130 PENUP
3140 MOVE 0,0
3150 !
3160 RETURN
3170 !
3180 !-----
3190 !
3200 Plot_data: ! PLOTS TO DATA SELECTED
3210 !
3220 VIEWPORT 13.100*RATIO,10.90
3230 WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3240 !
3250 IF C2=1 THEN 3290
3260 IF C2=2 THEN 3340
3270 IF C2=3 THEN 3390
3280 !
3290 FOR I=1 TO K
3300 PLOT Cod(I),Lod(I)
3310 NEXT I
3320 GOTO 3430
3330 !
3340 FOR I=1 TO K
3350 PLOT Def1(I),Lod(I)
3360 NEXT I
3370 GOTO 3430
3380 !
3390 FOR I=1 TO C1
3400 PLOT Delta_a(K2),J(K2)
3410 NEXT I
3420 !
3430 PENUP
3440 BEEP
3450 RETURN ! RETURNS TO SETUP_PLOTTER
3460 !
3470 !-----
3480 !
3490 END

```


APPENDIX G

PRECRACK OUTPUT

USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION
HAS BEEN ENTERED FOR: HY80-5B

WIDTH = .9469 NOTCH LENGTH = .444
Bmax = .496 Bmin = .394
HALF SPAN = 1.894 POISSON'S RATIO = .3
YIELD STRENGTH = 86600 ULTIMATE TS = 100000
ELASTIC MODULUS = 2.9E+7 FLOW STRESS = 93300

CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: HY80-5B
WIDTH = 24.05126 NOTCH LENGTH = 11.2776
Bmax = 12.5984 Bmin = 10.0076
YIELD STRENGTH = 597085.603738 ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497E+8 FLOW STRESS = 643280.448369

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .444 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .12414 in
CRACK LENGTH AT 50% OF EXTENSION = .50607 in
Pmax = 3272.42651647 Lbs Pmin = 163.621325823 Lbs
Delp = 3108.80519064 Lbs Kmax = 82563.7466931
DELTA_K = 78435.5593585 in^{.5} DELTA_KE = 40000 in^{.5}

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1668.84843723 Lbs Pmin = 83.4424218615 Lbs
DELTA_P = 1585.40601537 Lbs Kmax = 42105.2631579

CONVERSION DATA

FOR LOAD: -1779.288646 N/V (-400 Lbs/V)
FOR COD: .0508 mm/V (.002 in/V)
FOR DEFLECTION: -12.7 mm/V (-.5 in/V)
U = .07

a/W = .732186117982 in CRACK LENGTH = .693307035117 in

LOAD (lbs)	COD (in)	COD (Volts)
200	.00256290169302	1.28145084651
300	.00384435253953	1.92217626976
400	.00512580338604	2.56290169302
500	.00640725423255	3.20362711627
600	.00768870507906	3.84435253953
700	.00897015592557	4.48507796278
800	.0102516067721	5.12580338604
900	.0115330576186	5.76652880929
1000	.0128145084651	6.40725423255
1100	.0140959593116	7.0479796558
1200	.0153774101581	7.68870507906
1300	.0166588610046	8.32943050231
1400	.0179403118511	8.97015592557
1500	.0192217626976	9.61088134882
1600	.0205032135441	10.2516067721
1700	.0217846643907	10.8923321953
1800	.0230661152372	11.5330576186

U = .075

a/W = .713968763392 in CRACK LENGTH = .676057022056 in

LOAD (lbs)	COD (in)	COD (Volts)
200	.00220863052208	1.10431526104
300	.00331294578312	1.65647289156
400	.00441726104416	2.20863052208
500	.00552157630521	2.7607881526

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USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION
HAS BEEN ENTERED FOR: HY80-5B

WIDTH = .9469 NOTCH LENGTH = .444
Bmax = .496 Bmin = .394
HALF SPAN = 1.394 POISSON'S RATIO = .3
YIELD STRENGTH = 86600 ULTIMATE TS = 100000
ELASTIC MODULUS = 2.9E+7 FLOW STRESS = 93300

CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: HY80-5B
WIDTH = 24.05126 NOTCH LENGTH = 11.2776
Bmax = 12.5984 Bmin = 10.0076
YIELD STRENGTH = 597085.603738 ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497E+8 FLOW STRESS = 643280.448363

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .444 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .12414 in
CRACK LENGTH AT 50% OF EXTENSION = .50607 in
Pmax = 3272.42651647 Lbs Pmin = 163.621325823 Lbs
Delp = 3108.80519064 Lbs Kmax = 82563.7466931
DELTA_K = 78435.5593585 in^{.5} DELTA_KE = 40000 in^{.5}

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1668.84843723 Lbs Pmin = 83.4424218615 Lbs
DELTA_P = 1585.40601537 Lbs Kmax = 42105.2631579

CONVERSION DATA
FOR LOAD: -1779.288646 N/V (-400 Lbs/V)
FOR COD: .0508 mm/V (.002 in/V)
FOR DEFLECTION: -12.7 mm/V (-.5 in/V)

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .477215195165 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .47792545433 TO .476507410981 in
USING COD COMPLIANCE OF: 2.84104311054E-6 in/Lb = 1.62905173472E-5 mm/N
WITH A CORRELATION OF: .999771386472 FROM 106 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .477198279382 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .478064054454 TO .476336178981 in
USING COD COMPLIANCE OF: 2.84076126094E-6 in/Lb = 1.63037750213E-5 mm/N
WITH A CORRELATION OF: .99959257929 FROM 124 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .477198279382 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0909417206182 in
CRACK LENGTH AT 50% OF EXTENSION = .489470860309 in
Pmax = 2854.63728597 Lbs Pmin = 142.731864298 Lbs
Delp = 2711.90542167 Lbs Kmax = 80310.2753096
DELTA_K = 76294.7615441 in^{.5} DELTA_KE = 40000 in^{.5}

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1496.63606161 Lbs Pmin = 74.8318030804 Lbs
DELTA_P = 1421.80425853 Lbs Kmax = 42105.2631579

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .499315101398 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .500434044632 TO .498202259284 in
USING COD COMPLIANCE OF: $3.23884557474E-6$ in/Lb = $1.86189031428E-5$ mm/N
WITH A CORRELATION OF: .999477933275 FROM 94 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .499773214641 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .50177796077 TO .497787999797 in
USING COD COMPLIANCE OF: $3.24775972936E-6$ in/Lb = $1.8769892409E-5$ mm/N
WITH A CORRELATION OF: .999019979378 FROM 57 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-SB:

CURRENT CRACK LENGTH = .499773214641 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0683667853593 in
CRACK LENGTH AT 50% OF EXTENSION = .47818339268 in
Pmax = 1034.73227996 Lbs Pmin = 51.736613998 Lbs
Delp = 982.995665963 Lbs Kmax = 31462.7523142
DELTA_K = 29889.6146985 in^{1.5} DELTA_KE = 29000 in^{1.5}

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1003.9351936 Lbs Pmin = 50.1967596798 Lbs
DELTA_P = 953.738433917 Lbs Kmax = 30526.3157895

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .523238325069 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .524952826657 TO .521538109085 in
USING COD COMPLIANCE OF: $3.74604099481E-6$ in/Lb = $2.16181567648E-5$ mm/N
WITH A CORRELATION OF: .999183456903 FROM 61 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .519260644793 in FROM MEASUREMENT # 2

WITH 95%CONFIDENCE INTERVAL FROM .521257634776 TO .51728301025 in
USING COD COMPLIANCE OF: 3.65545467572E-5 in/Lb = 2.11309694446E-5 mm/N
WITH A CORRELATION OF: .998905179767 FROM 61 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .520164834896 in FROM MEASUREMENT # 3
WITH 95%CONFIDENCE INTERVAL FROM .521732160051 TO .51860945694 in
USING COD COMPLIANCE OF: 3.67581279234E-6 in/Lb = 2.11927866299E-5 mm/N
WITH A CORRELATION OF: .999107091656 FROM 79 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .520164834896 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0479751651041 in
CRACK LENGTH AT 50% OF EXTENSION = .467987582552 in
Pmax = 942.504620395 Lbs Pmin = 47.1252310197 Lbs
Delp = 895.379389375 Lbs Kmax = 30831.6649108
DELTA_K = 29290.0816653 in^{.5} DELTA_KE = 29000 in^{.5}

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 933.170289649 Lbs Pmin = 46.6585144825 Lbs
DELTA_P = 886.511775167 Lbs Kmax = 30526.3157895

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .557542180253 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .559342565208 TO .555757596687 in
USING COD COMPLIANCE OF: 4.6522934609E-6 in/Lb = 2.6877228564E-5 mm/N
WITH A CORRELATION OF: .999026349545 FROM 60 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .556985314799 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .559603140017 TO .554400760935 in
USING COD COMPLIANCE OF: 4.63555555373E-6 in/Lb = 2.69227537518E-5 mm/N
WITH A CORRELATION OF: .998286279816 FROM 51 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .55746232304 in FROM MEASUREMENT # 3
WITH 95%CONFIDENCE INTERVAL FROM .558944733365 TO .555990641885 in
USING COD COMPLIANCE OF: 4.64988856512E-6 in/Lb = 2.68079074153E-5 mm/N
WITH A CORRELATION OF: .999219985095 FROM 70 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .55746232304 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0106776769602 in
CRACK LENGTH AT 50% OF EXTENSION = .44933883848 in
Pmax = 784.95101444 Lbs Pmin = 39.247550722 Lbs
Delp = 745.703463718 Lbs Kmax = 29594.1425953
DELTA_K = 28114.4354655 in^{.5} DELTA_KE = 29000 in^{.5}

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .556873246958 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .558630143876 TO .555131398279 in
USING COD COMPLIANCE OF: 4.63219612139E-6 in/Lb = 2.67532481877E-5 mm/N

WITH A CORRELATION OF: .999174171419 FROM 54 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-58:

CURRENT CRACK LENGTH = .556873246958 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0112667530417 in
CRACK LENGTH AT 50% OF EXTENSION = .449633376521 in
Pmax = 787.327495262 Lbs Pmin = 39.3663747631 Lbs
Delp = 747.961120499 Lbs Kmax = 29614.5302835
DELTA_K = 28133.9037694 in^{.5} DELTA_KE = 29000 in^{.5}

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:

CRACK LENGTH = .560000734225 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .56106384425 TO .55893721925 in
USING COD COMPLIANCE OF: 4.72709402318E-6 in/Lb = 2.71807983847E-5 mm/N
WITH A CORRELATION OF: .99939646638 FROM 101 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:

CRACK LENGTH = .562208107534 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .56343540602 TO .560988120658 in
USING COD COMPLIANCE OF: 4.79552996551E-6 in/Lb = 2.76035025025E-5 mm/N
WITH A CORRELATION OF: .99948124671 FROM 67 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY30-58:

CURRENT CRACK LENGTH = .562208107534 in
OPTIMUM CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .00593189246594 in
CRACK LENGTH AT 50% OF EXTENSION = .446965946233 in
Pmax = 765.936366326 Lbs Pmin = 38.2968183163 Lbs
Delp = 727.63954801 Lbs Kmax = 29428.399829
DELTA_K = 27957.4548376 in^{.5} DELTA_KE = 29000 in^{.5}

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:

CRACK LENGTH = .564151471472 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .565674835605 TO .562639453926 in
USING COD COMPLIANCE OF: 4.85680462792E-6 in/Lb = 2.80112437329E-5 mm/N
WITH A CORRELATION OF: .999133273453 FROM 72 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:

CRACK LENGTH = .568361917225 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .569305393318 TO .567422811142 in
USING COD COMPLIANCE OF: 4.99294827909E-6 in/Lb = 2.86883916896E-5 mm/N
WITH A CORRELATION OF: .999601697254 FROM 84 DATA POINTS.

PRECRACKING IS COMPLETED!

FINAL CRACK LENGTH = .568361917225
CORRELATION OF DATA = .999601697254

REMOVE SPECIMEN FROM MTS.

APPENDIX H

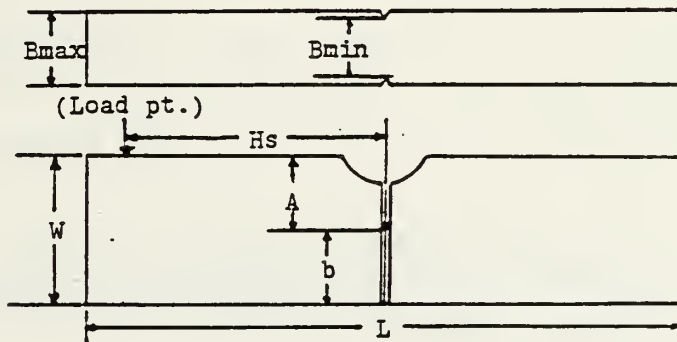
J_INTGL OUTPUT

THREE POINT BEND SPECIMEN

TEST REPORT

SPECIMEN I.D. HY80-5B MATERIAL HY80 ORIENTATION T-S

Date 12/13/83 Operator TRITCHLER Test Temp 21C



$W = 0.9469"$ $A = 0.444"$ $b = 0.5029"$ $L = 4.5"$

$H_s = 1.894"$ $B_{max} = 0.4960"$ $B_{min} = 0.394"$

$Y_s = 86600 \text{ psi}$ $U_s = 100000 \text{ psi}$ $F_s = 93300 \text{ psi}$

Poisson's ratio = 0.3 Elastic Modulus = $2.9 \times 10^7 \text{ psi}$

Comments:

HY80 BASE METAL FROM PREHEATED WELD

PRECRACKED ON 12/11/83; J-TEST ON 12/13/83 $\Rightarrow J_{IC} = 142 \text{ KJ/m}^2$

USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION
HAS BEEN ENTERED FOR: HY80-5B

WIDTH = .9469 NOTCH LENGTH = .444
Bmax = .496 Bmin = .394
HALF SPAN = 1.894 POISSON'S RATIO = .3
YIELD STRENGTH = 86600 ULTIMATE TS = 100000
ELASTIC MODULUS = 2.9E+7 FLOW STRESS = 93300

CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: HY80-5B
WIDTH = 24.05126 NOTCH LENGTH = 11.2776
Bmax = 12.5984 Bmin = 10.0076
HALF SPAN = 48.1076 POISSON'S RATIO = .3
YIELD STRENGTH = 597085.603738 ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497E+8 FLOW STRESS = 643280.448369

CONVERSION DATA
FOR LOAD: -1779.288646 N/V (400 Lbs/V)
FOR COD: .254 mm/V (.01 in/V)
FOR DEFLECTION: -1.27 mm/V (.05 in/V)

GIVEN a = .568 inches THEN:
Pmax = 895.290182804 Lbs FROM ASTM E813-81

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
INITIAL CRACK LENGTH = 14.3875382557 mm FROM MEASUREMENT # 1
WITH 95% CONFIDENCE INTERVAL FROM 14.4079726404 TO 14.3671845862 mm
USING COD COMPLIANCE OF: 2.81520064535E-5 mm/N
WITH A CORRELATION OF: .999323843963 FROM 189 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
INITIAL CRACK LENGTH = 14.4326755548 mm FROM MEASUREMENT # 2
WITH 95% CONFIDENCE INTERVAL FROM 14.4442813846 TO 14.42109582 mm
USING COD COMPLIANCE OF: 2.84829954475E-5 mm/N
WITH A CORRELATION OF: .99984474937 FROM 134 DATA POINTS.

INITIAL CRACK LENGTH = 14.4455712237 mm FROM MEASUREMENT # 3
WITH 95% CONFIDENCE INTERVAL FROM 14.4565506791 TO 14.434615129 mm
USING COD COMPLIANCE OF: 2.85784514764E-5 mm/N
WITH A CORRELATION OF: .999816522357 FROM 176 DATA POINTS.

---- UNLOADING # 1 ----

CRACK LENGTH = 14.4487507815 mm DELTA a = .016075226716 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.4693514291 TO 14.4282322251

TOTAL # DATA POINTS = 632 # DATA POINTS THIS UNLOADING = 128
CORRELATION = .999529434569
COD COMPLIANCE = 2.87555293817E-5 mm/N

AREA = 711.365042717 N*mm
J = 14.8049806501 KJ/m²
MAX LOAD LINE DEFLECTION = .24034834255 mm
CHANGE IN COD = .00109982 mm

---- UNLOADING # 2 ----

CRACK LENGTH = 14.4711513219 mm DELTA a = .0384757670308 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.4927078135 TO 14.4496847244

TOTAL # DATA POINTS = 947 # DATA POINTS THIS UNLOADING = 132
CORRELATION = .999467111958
COD COMPLIANCE = 2.89307913363E-5 mm/N

AREA = 1693.69098454 N*mm
J = 35.2970225265 KJ/m²
MAX LOAD LINE DEFLECTION = .382347556072 mm
CHANGE IN COD = .0008382 mm

---- UNLOADING # 3 ----

CRACK LENGTH = 14.4875164202 mm DELTA a = .0548408654168 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.5143346851 TO 14.460837178

TOTAL # DATA POINTS = 1300 # DATA POINTS THIS UNLOADING = 157
CORRELATION = .999017363069
COD COMPLIANCE = 2.90942709989E-5 mm/N

AREA = 3033.0003923 N*mm
J = 63.28381022 KJ/m²
MAX LOAD LINE DEFLECTION = .543433314464 mm
CHANGE IN COD = .0009398 mm

---- UNLOADING # 4 ----

CRACK LENGTH = 14.5414951598 mm DELTA a = .108819604992 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.5601316376 TO 14.5229259715

TOTAL # DATA POINTS = 1670 # DATA POINTS THIS UNLOADING = 109
CORRELATION = .999675611283
COD COMPLIANCE = 2.94442988118E-5 mm/N

AREA = 5208.32927275 N*mm
J = 108.998439815 KJ/m²
MAX LOAD LINE DEFLECTION = .782918890293 mm

CHANGE IN COD = .0007874 mm

---- UNLOADING # 5 ----

CRACK LENGTH = 14.7407494376 mm DELTA a = .308073862773 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.7587196422 TO 14.7228419911

TOTAL # DATA POINTS = 2060 # DATA POINTS THIS UNLOADING = 95
CORRELATION = .999731105207
COD COMPLIANCE = 3.10248861726E-5 mm/N

AREA = 8216.7400787 N*mm
J = 169.858689852 KJ/m²
MAX LOAD LINE DEFLECTION = 1.10455056629 mm
CHANGE IN COD = .0008636 mm

---- UNLOADING # 6 ----

CRACK LENGTH = 14.8152586049 mm DELTA a = .382583050059 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.8481840789 TO 14.782543466

TOTAL # DATA POINTS = 2280 # DATA POINTS THIS UNLOADING = 138
CORRELATION = .998642018089
COD COMPLIANCE = 3.17719219461E-5 mm/N

AREA = 9001.97373669 N*mm
J = 185.342172083 KJ/m²
MAX LOAD LINE DEFLECTION = 1.18989063161 mm
CHANGE IN COD = .0009906 mm

---- UNLOADING # 7 ----

CRACK LENGTH = 14.8695206824 mm DELTA a = .436845127588 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.8849566722 TO 14.8541311238

TOTAL # DATA POINTS = 2531 # DATA POINTS THIS UNLOADING = 147
CORRELATION = .999677856393
COD COMPLIANCE = 3.20855798284E-5 mm/N

AREA = 9678.11102926 N*mm
J = 198.876552682 KJ/m²
MAX LOAD LINE DEFLECTION = 1.26297067275 mm
CHANGE IN COD = .0004572 mm

---- UNLOADING # 8 ----

CRACK LENGTH = 15.0148445295 mm DELTA a = .582163973634 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.0416778385 TO 14.9881516089

TOTAL # DATA POINTS = 2761 # DATA POINTS THIS UNLOADING = 97
CORRELATION = .999364204197
COD COMPLIANCE = 3.34673392487E-5 mm/N

AREA = 10586.6765231 N*mm
J = 215.448776655 KJ/m²
MAX LOAD LINE DEFLECTION = 1.36396114491 mm

CHANGE IN COD = .0006604 mm

----- UNLOADING # 9 -----

CRACK LENGTH = 15.1216765395 mm DELTA a = .689000984704 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.1358606171 TO 15.1075318754

TOTAL # DATA POINTS = 3042 # DATA POINTS THIS UNLOADING = 119
CORRELATION = .99977636544
COD COMPLIANCE = 3.43343078736E-5 mm/N

AREA = 11709.4655627 N*mm
J = 237.699077286 KJ/m²
MAX LOAD LINE DEFLECTION = 1.49020183752 mm
CHANGE IN COD = .0005842 mm

----- UNLOADING # 10 -----

CRACK LENGTH = 15.2624877891 mm DELTA a = .829812234314 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.2760292626 TO 15.2489823604

TOTAL # DATA POINTS = 3394 # DATA POINTS THIS UNLOADING = 167
CORRELATION = .999700915055
COD COMPLIANCE = 3.56785340653E-5 mm/N

AREA = 12983.4083914 N*mm
J = 262.394826944 KJ/m²
MAX LOAD LINE DEFLECTION = 1.63760345064 mm
CHANGE IN COD = .0007366 mm

----- UNLOADING # 11 -----

CRACK LENGTH = 15.3993548961 mm DELTA a = .966679341294 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.4107739959 TO 15.3879615278

TOTAL # DATA POINTS = 3867 # DATA POINTS THIS UNLOADING = 204
CORRELATION = .999734089719
COD COMPLIANCE = 3.70351235759E-5 mm/N

AREA = 14557.9277896 N*mm
J = 294.038000741 KJ/m²
MAX LOAD LINE DEFLECTION = 1.82262379631 mm
CHANGE IN COD = .0004318 mm

----- UNLOADING # 12 -----

CRACK LENGTH = 15.669999544 mm DELTA a = 1.2373239892 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.6847004127 TO 15.6553416287

TOTAL # DATA POINTS = 4267 # DATA POINTS THIS UNLOADING = 154
CORRELATION = .999652892868
COD COMPLIANCE = 4.00050024785E-5 mm/N

AREA = 16330.4160222 N*mm
J = 325.442585526 KJ/m²
MAX LOAD LINE DEFLECTION = 2.03825076401 mm

CHANGE IN COD = .0013462 mm

---- UNLOADING # 13 ----

CRACK LENGTH = 15.8781418346 mm DELTA a = 1.44546627973 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.8901071812 TO 15.8662051558

TOTAL # DATA POINTS = 4710 # DATA POINTS THIS UNLOADING = 208
CORRELATION = .999677232181
COD COMPLIANCE = 4.24377123766E-5 mm/N

AREA = 17933.7183158 N*mm
J = 355.360006494 KJ/m²
MAX LOAD LINE DEFLECTION = 2.24213294335 mm
CHANGE IN COD = .000508 mm

---- UNLOADING # 14 ----

CRACK LENGTH = 16.1357477216 mm DELTA a = 1.7030721668 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.1463233402 TO 16.1251947229

TOTAL # DATA POINTS = 5206 # DATA POINTS THIS UNLOADING = 239
CORRELATION = .999696024845
COD COMPLIANCE = 4.57508725867E-5 mm/N

AREA = 19646.0705407 N*mm
J = 385.620902249 KJ/m²
MAX LOAD LINE DEFLECTION = 2.47449867471 mm
CHANGE IN COD = .0004826 mm

---- UNLOADING # 15 ----

CRACK LENGTH = 16.4193583405 mm DELTA a = 1.98668278568 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.4364102869 TO 16.4023658462

TOTAL # DATA POINTS = 5648 # DATA POINTS THIS UNLOADING = 194
CORRELATION = .999324290353
COD COMPLIANCE = 4.99261698493E-5 mm/N

AREA = 21264.009056 N*mm
J = 412.083508069 KJ/m²
MAX LOAD LINE DEFLECTION = 2.70365472703 mm
CHANGE IN COD = .0005334 mm

---- UNLOADING # 16 ----

CRACK LENGTH = 16.9028626935 mm DELTA a = 2.47018713865 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.9171113874 TO 16.888656585

TOTAL # DATA POINTS = 6102 # DATA POINTS THIS UNLOADING = 162
CORRELATION = .999564028818
COD COMPLIANCE = 5.80350094828E-5 mm/N

AREA = 22950.1834392 N*mm
J = 428.162914109 KJ/m²
MAX LOAD LINE DEFLECTION = 2.96634800605 mm

DATA FROM J vs DELTA_a PLOT

SLOPE = 164.148013927 Y-INTERCEPT = 123.933075018
CORRELATION = .99667195294 FROM 9 DATA POINTS.

J1c = 142.05774949

TEST IS OVER!

UNLOADING #	DELTA_a(mm)	J(KJ/m ²)
1	.016075	14.8
2	.038476	35.3
3	.054841	63.3
4	.108820	109.0
5	.308074	169.9
6	.382583	185.3
7	.436845	198.9
8	.582169	215.4
9	.689001	237.7
10	.829812	262.4
11	.966679	294.0
12	1.237324	325.4
13	1.445466	355.4
14	1.703072	385.6
15	1.986683	412.1
16	2.470187	428.2

DATA FROM J vs DELTA_a PLOT

SLOPE = 164.148013927 Y-INTERCEPT = 123.933075018
CORRELATION = .99667195294 FROM 9 DATA POINTS.

J1c = 142.05774949

TEST IS OVER!

APPENDIX I

J DATA OUTPUT

WHAT DATA FILE DO YOU WISH TO READ?

J-INTEGRAL TEST OF HY80-5B BY: KURT

DATE: 12-13-83 TIME: 10:35

a0= 14.4326755548 WITH 95% CONFIDENCE INTERVAL
FROM 14.4442813846 TO 14.42109582

FROM COMPLIANCE = 2.84829954475E-5

CORRELATION= .99984474937 FROM 176 DATA POINTS

DO YOU WANT A HARD COPY OF THIS INFORMATION?

FROM UNLOADING # 1 RECORDED 128 DATA POINTS
COD COMPLIANCE = 2.87555293817E-5 mm/N CORRELATION = .999529434569
CRACK LENGTH = 14.4487507815 mm DELTA_A = .016075226716 mm
95% CONFIDENCE INTERVAL FROM 14.4693514291 mm TO 14.4282322251 mm
AREA = 711.365042717 N*mm J = 14.8049806501 KPa*mm
DATA POINT INDEXES FROM 504 TO 632 WERE USED.

FROM UNLOADING # 2 RECORDED 132 DATA POINTS
COD COMPLIANCE = 2.89307913363E-5 mm/N CORRELATION = .999467111958
CRACK LENGTH = 14.4711513219 mm DELTA_A = .0384757670308 mm
95% CONFIDENCE INTERVAL FROM 14.4927078135 mm TO 14.4496847244 mm
AREA = 1693.69098454 N*mm J = 35.2970225265 KPa*mm
DATA POINT INDEXES FROM 815 TO 947 WERE USED.

FROM UNLOADING # 3 RECORDED 157 DATA POINTS
COD COMPLIANCE = 2.9042709989E-5 mm/N CORRELATION = .999017363069
CRACK LENGTH = 14.4875164202 mm DELTA_A = .0548408654168 mm
95% CONFIDENCE INTERVAL FROM 14.5143346851 mm TO 14.460837178 mm
AREA = 3033.0003923 N*mm J = 63.28381022 KPa*mm
DATA POINT INDEXES FROM 1143 TO 1300 WERE USED.

FROM UNLOADING # 4 RECORDED 109 DATA POINTS
COD COMPLIANCE = 2.94442988118E-5 mm/N CORRELATION = .999675611283
CRACK LENGTH = 14.5414951598 mm DELTA_A = .108819604992 mm
95% CONFIDENCE INTERVAL FROM 14.5601316376 mm TO 14.5229259715 mm
AREA = 5208.32927275 N*mm J = 108.998439815 KPa*mm
DATA POINT INDEXES FROM 1561 TO 1670 WERE USED.

FROM UNLOADING # 5 RECORDED 95 DATA POINTS
COD COMPLIANCE = 3.10248861726E-5 mm/N CORRELATION = .999731105207

CRACK LENGTH = 14.7407494376 mm DELTA_A = .308073882773 mm
95% CONFIDENCE INTERVAL FROM 14.7587196422 mm TO 14.7228419911 mm
AREA = 3216.7400787 N*mm J = 169.858689852 KPa*mm
DATA POINT INDEXES FROM 1965 TO 2060 WERE USED.

FROM UNLOADING # 6 RECORDED 138 DATA POINTS
COD COMPLIANCE = 3.17719219461E-5 mm/N CORRELATION = .998642018089
CRACK LENGTH = 14.8152586049 mm DELTA_A = .382583050059 mm
95% CONFIDENCE INTERVAL FROM 14.8481840789 mm TO 14.782543466 mm
AREA = 9001.97373669 N*mm J = 185.342172083 KPa*mm
DATA POINT INDEXES FROM 2142 TO 2280 WERE USED.

FROM UNLOADING # 7 RECORDED 147 DATA POINTS
COD COMPLIANCE = 3.20855798284E-5 mm/N CORRELATION = .999677856393
CRACK LENGTH = 14.8695206824 mm DELTA_A = .436845127588 mm
95% CONFIDENCE INTERVAL FROM 14.8849566722 mm TO 14.8541311238 mm
AREA = 9678.11102926 N*mm J = 198.876552682 KPa*mm
DATA POINT INDEXES FROM 2384 TO 2531 WERE USED.

FROM UNLOADING # 8 RECORDED 97 DATA POINTS
COD COMPLIANCE = 3.34673392487E-5 mm/N CORRELATION = .999364204197
CRACK LENGTH = 15.0148445285 mm DELTA_A = .582168973634 mm
95% CONFIDENCE INTERVAL FROM 15.0416778385 mm TO 14.9881516089 mm
AREA = 10586.6765231 N*mm J = 215.448776655 KPa*mm
DATA POINT INDEXES FROM 2664 TO 2761 WERE USED.

FROM UNLOADING # 9 RECORDED 119 DATA POINTS
COD COMPLIANCE = 3.43343078736E-5 mm/N CORRELATION = .99977636544
CRACK LENGTH = 15.1216765395 mm DELTA_A = .689000984704 mm
95% CONFIDENCE INTERVAL FROM 15.1358606171 mm TO 15.1075318754 mm
AREA = 11709.4655627 N*mm J = 237.699077286 KPa*mm
DATA POINT INDEXES FROM 2923 TO 3042 WERE USED.

FROM UNLOADING # 10 RECORDED 167 DATA POINTS
COD COMPLIANCE = 3.56785340653E-5 mm/N CORRELATION = .999700915055
CRACK LENGTH = 15.2624877891 mm DELTA_A = .829812234314 mm
95% CONFIDENCE INTERVAL FROM 15.2760292626 mm TO 15.2489823604 mm
AREA = 12983.4083914 N*mm J = 262.394826944 KPa*mm
DATA POINT INDEXES FROM 3227 TO 3394 WERE USED.

FROM UNLOADING # 11 RECORDED 204 DATA POINTS
COD COMPLIANCE = 3.70351235759E-5 mm/N CORRELATION = .999734089719
CRACK LENGTH = 15.3993548961 mm DELTA_A = .966679341294 mm
95% CONFIDENCE INTERVAL FROM 15.4107739959 mm TO 15.3879615278 mm
AREA = 14557.9277896 N*mm J = 294.038000741 KPa*mm
DATA POINT INDEXES FROM 3663 TO 3867 WERE USED.

FROM UNLOADING # 12 RECORDED 154 DATA POINTS
COD COMPLIANCE = 4.00050024785E-5 mm/N CORRELATION = .999652892868
CRACK LENGTH = 15.669999544 mm DELTA_A = 1.2373239892 mm
95% CONFIDENCE INTERVAL FROM 15.6847004127 mm TO 15.6553416287 mm
AREA = 16330.4160222 N*mm J = 325.442585526 KPa*mm
DATA POINT INDEXES FROM 4113 TO 4267 WERE USED.

FROM UNLOADING # 13 RECORDED 208 DATA POINTS
COD COMPLIANCE = $4.24377123766E-5$ mm/N CORRELATION = .999677232181
CRACK LENGTH = 15.8781418346 mm DELTA_A = 1.44546627973 mm
95% CONFIDENCE INTERVAL FROM 15.8901071812 mm TO 15.8662051558 mm
AREA = 17933.7183158 N*mm J = 355.360006494 KPa*mm
DATA POINT INDEXES FROM 4502 TO 4710 WERE USED.

FROM UNLOADING # 14 RECORDED 239 DATA POINTS
COD COMPLIANCE = $4.57508725867E-5$ mm/N CORRELATION = .999696024845
CRACK LENGTH = 16.1357477216 mm DELTA_A = 1.7030721668 mm
95% CONFIDENCE INTERVAL FROM 16.1463233402 mm TO 16.1251947229 mm
AREA = 19646.0705407 N*mm J = 385.620902249 KPa*mm
DATA POINT INDEXES FROM 4967 TO 5206 WERE USED.

FROM UNLOADING # 15 RECORDED 194 DATA POINTS
COD COMPLIANCE = $4.99261698493E-5$ mm/N CORRELATION = .999324290353
CRACK LENGTH = 16.4193583405 mm DELTA_A = 1.98668278568 mm
95% CONFIDENCE INTERVAL FROM 16.4364102869 mm TO 16.4023658462 mm
AREA = 21264.009056 N*mm J = 412.083508069 KPa*mm
DATA POINT INDEXES FROM 5454 TO 5648 WERE USED.

FROM UNLOADING # 16 RECORDED 162 DATA POINTS
COD COMPLIANCE = $5.80350094828E-5$ mm/N CORRELATION = .999564028818
CRACK LENGTH = 16.9028626935 mm DELTA_A = 2.47018713865 mm
95% CONFIDENCE INTERVAL FROM 16.9171113874 mm TO 16.888656585 mm
AREA = 22950.1834392 N*mm J = 428.162914109 KPa*mm
DATA POINT INDEXES FROM 5940 TO 6102 WERE USED.

DATA FROM au FGR:HY80-58 BY: KURT

TESTED ON: 12-13-83 TIME: 10:35

PT #	LOAD (N)	DEFLECTION (mm)	CDD (mm)
1	2262.5	.079424	.060576
2	2261.7	.074706	.060576
3	2265.2	.076740	.060637
4	2277.3	.079003	.061003
5	2350.8	.093469	.063589
6	2409.0	.094978	.065014
7	2442.3	.095827	.065895
8	2463.4	.096491	.066429
9	2478.9	.096968	.066954
10	2496.2	.097378	.067280
11	2505.2	.097666	.067627
12	2515.4	.098165	.067772
13	2526.1	.098554	.068207
14	2539.6	.099114	.068511
15	2554.0	.099864	.068969
16	2570.4	.100177	.069411
17	2595.3	.101411	.070231
18	2624.1	.102889	.071107
19	2653.4	.103775	.072045
20	2688.5	.104678	.072903
21	2722.7	.106054	.073863
22	2746.9	.106721	.074519
23	2764.1	.107052	.075024
24	2779.2	.108077	.075443
25	2799.9	.108725	.075956
26	2820.2	.109596	.076655
27	2837.8	.110482	.077142
28	2854.0	.110667	.077617
29	2873.4	.112035	.078313
30	2939.6	.114805	.080284
31	2984.9	.115696	.081471

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6085	5686.4	2.954239	2.460422
6086	5692.7	2.954786	2.460701
6087	5699.1	2.955204	2.461209
6088	5704.9	2.955629	2.461616
6089	5716.5	2.956736	2.462454
6090	5731.8	2.957790	2.463394
6091	5747.5	2.959093	2.464359
6092	5761.2	2.959789	2.465172
6093	5768.6	2.960445	2.465730
6094	5777.0	2.961089	2.466442
6095	5785.5	2.961730	2.467051
6096	5792.8	2.962262	2.467534
6097	5803.0	2.963643	2.468321
6098	5812.6	2.964142	2.469007
6099	5818.6	2.964692	2.469540
6100	5824.1	2.965503	2.470175
6101	5830.0	2.965801	2.470582
6102	5836.8	2.966848	2.471293

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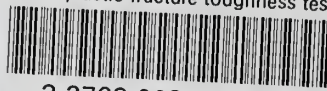
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